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REPORT OF FIELD COLLECTIONS AND LABORATORY DIAGNOSTIC ASSAY,(U)
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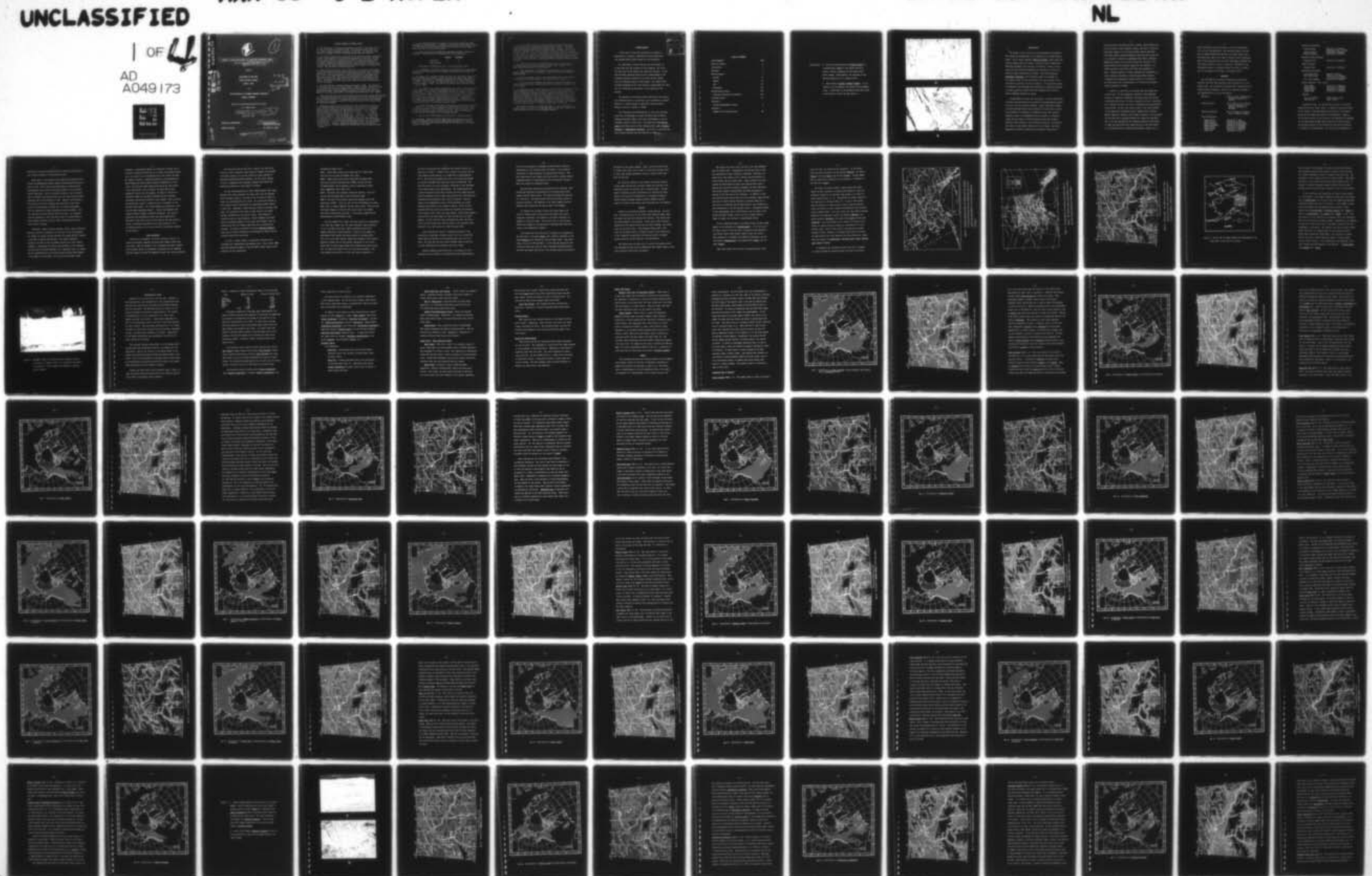

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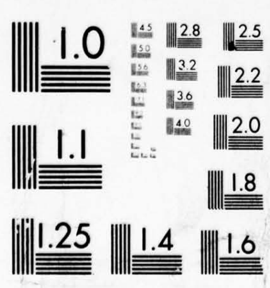

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6 REPORT OF FIELD COLLECTIONS and LABORATORY DIAGNOSTIC ASSAY

Contract Number (15) DA-42-007-AMC-121 (R) New

Between

DEPARTMENT OF THE ARMY

DUGWAY PROVING GROUNDS

DUGWAY, UTAH

and

THE UNIVERSITY OF OKLAHOMA RESEARCH INSTITUTE

NORMAN, OKLAHOMA

Ecology and Epidemiology Research Studies

in a Remote Area

(11) 30 Mar 65 (12) 289 p.

March 30, 1965

PRINCIPAL INVESTIGATOR: (10) Cluff E. Hopla
Professor of Zoology

PROJECT OFFICER: Dr. Keith L. Smart

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ECOLOGY STUDIES IN CENTRAL ALASKA

1. The University of Oklahoma was awarded a contract in July 1964 to conduct an E & E Survey in Central Alaska. The Principal Investigator was Dr. Cluff E. Hopla, Chairman, Department of Zoology. Dr. Hopla had been conducting ecological studies in Central Alaska since the mid-50's.

2. The contract included two major aspects of study (1) conduct literature survey on the zoonoses and blood-sucking arthropods in the arctic and (2) conduct field studies to determine: the kinds of birds and mammals found in Central Alaska, their seasonal patterns and fluctuations, population densities, ectoparasite relationships, and collect samples of tissue, sera and parasites for the laboratory analysis seeking evidence of tularemia and Q fever. See University of Oklahoma reports.

3. During 1964 the majority of the field work was conducted in the Tanana Valley with additional study areas at Livingood, Fairbanks, Paxon and Eagle. See Report of Field Collections and Laboratory Diagnostic Assay, 30 March 1965. Also, this report provides a basic description of the mammal distribution in the area. Page 120 and 123 describe the distribution of the caribou in Alaska, while Map 78 and 79 on page 124 and 125 indicated its range. Page 228 of the 1965 report lists three sero-positive reactions of Q fever in caribou.

4. The field studies continued through the summer of 1965. The majority of the field work was done during mid-April through October. Limited studies on carnivores and large game mammals were conducted through the cold and dark winter months. Major emphasis was placed on studies along Delta Creek. There was no ecology work done in the Gerstle River area east of Ft. Greely.

Table 2 on page 18 of the 25 April 1966 report lists six caribou samples which were collected for diagnostic work. Comments on the caribou distribution are found on pages 26 and 27. A seropositive reaction for Q fever and tularemia was found in two caribou collected at Paxon Lake (south of Ft. Greely along the Richardson Highway).

5. During the summer and fall of 1966 and winter of 1967 the studies continued about the same as the previous years. See University of Oklahoma Report of Field Collections and Laboratory Diagnostic Assay, 5 May 1967. During October and November of 1966 and during March and April 1967, a special study was undertaken to secure serum samples and to tag caribou that were confined to the north slope of the Alaska range. This project was done cooperatively with the Alaska Department of Fish and Game. The fall samples were collected in the vicinity of Dry Creek (approximately 75 miles west of Ft. Greely) and the spring samples were taken near Portage Creek (near Dry Creek) and the area west of Delta Creek. See page 1 and 2 of the May 5, 1967 report. Details of the capture process is given on Page 10. During the report period 165 caribou were collected for the study. See page 15.

a. The behavior patterns of caribou in the Tanana Valley were very irregular and inconsistent. An example on page 24-25 is given where a herd of 2-5000 caribou were observed in March, the following day the largest group consisted of several small herds.

b. Page 37 lists those animals with antibodies against Q fever and tularemia. Caribou from the following areas were seropositive.

	Q fever	Tularemia
Dry Creek	5	3
Portage Creek	1	7

c. There were no observations made in the Gerstle River area.

d. An epilogue, 5 May 1967, describes some observations on the extreme variations and fluctuations of the mammals, specifically the caribou, in the arctic.

7. The report, E & E Research Studies in Alaska, 25 July 1968, covers the field and laboratory studies conducted from May 1967 through June 1968. The report also provides a composite comparison of the three years of work in Alaska. Table 1 on page 17 indicates the number of caribou collected during the spring of 1968. Very few if any caribou were collected during the fall of 1967.

a. An account on the caribou distribution and habits is given on pages 24-26. There is one pertinent observation that has been made by caribou researchers. "At the present time caribou are largely confined to the upland and northern tundra regions passing down to the marginal taiga (forests) in search of food during the winter months. Small bands of caribou are known to occur on the north slope of the Alaskan range". Originally, it was thought that the caribou migrated only a few miles, however, it is now known that animals tagged at Delta Creek were observed as far north as Dry Creek and vice versa. The distance was 30-50 miles.

b. Studies conducted during 1950 in the Wood-Delta River area estimated 300 caribou in the vicinity. During March 1968, 3,000 to 5,000 head were observed in one herd at Buchanan Creek. Two days later only small bands of about 500 caribou could be found in the area. This is indicative of how the numbers vary greatly and can disperse rapidly.

c. Page 27 of the 1968 report give study data on caribou movement.

8. The report, A Resume of Field Collections and Laboratory Diagnostic Assay from 1964-1968, dated 2 June 1969 covered the field work from the summer of 1968 thru April 1969 and provides an evaluation of all the data collected since 1964.

a. An analyses of figure 1 on page 2 shows the Gerstle River area on the margin of the taiga (forest) and the upland tundra. The upland tundra is generally considered the habitat for the caribou. It is the tundra that supports the mosses and lichens which constitute the dominant portion of the food eaten by the caribou. It has been mentioned previously that caribou on occasion, mainly during the winter, have been observed in wooded areas. But, also, it must be kept in mind that this big game animal is highly mobile, congregates in great numbers, disperses rapidly in a day or two into small herds and is extremely difficult to predict their behavior patterns.

b. Table 3 page 8 shows that 100% of the caribou collected were in the tundra area but on page 10 figure 4 samples were collected in an area classified as taiga or forested areas.

c. More commentary on the habits and distribution of the caribou is given on pages 23 and 25 and figure 7 on page 24 indicates the tagging-recovery areas.

d. Page 31 describes some of the inter-relationships of the caribou and buffalo in the Tanana Valley - also note figure 9 on page 33.

e. Table 13 page 32 indicates the results of serological studies of caribou collected in the Donnelly area along the Richardson Highway south of Ft. Greely.

9. In summary, the data collected during the period 1964-1969 indicates the extreme unpredictability of the caribou, in small herds, as related to their distribution, migration patterns, population variations and fluctuations, congregation patterns and other aspects of their ecology. The phenomenon observed one year may be totally absent or different from the preceding or next year. Field and laboratory studies have established that all the big game animals (moose, buffalo and caribou) in the interior of Alaska have evidence of tularemia, Q fever and brucella. All evidence indicates these zoonoses to be only a febrile type of infection.

Throughout the period in Alaska there were no field observations or related studies conducted in the Gerstle River complex (area south of the Alaskan Highway and east of the Richardson Highway).

ACKNOWLEDGMENTS

I would like to take this opportunity to express my appreciation to numerous individuals who have worked with this program during various phases of its development.

Dr. Keith Smart, Project Officer, has been helpful in so many ways from the inception of this program. His aid in the early part of the project was especially valuable. I have been favorably impressed with his basic understanding of the biological problems involved in the field and his insight into the laboratory phases of the program. Drs. Robert Elbel and Hardy Eschbaugh of his staff should be acknowledged for their part in collecting the mosquitoes in the beginning of the program.

The personnel at the United States Army Arctic Test Center, who cooperated with us in many ways, are too numerous to mention. However, Lt. Colonel Kermit H. Applewhite deserves special mention, as does Lt. Colonel J. Brophy.

The scientists called Taxonomists, in their ever questing search for new knowledge, sit upon the divine neck of Nature, changing scientific names to the utter bewilderment of one not thoroughly versed in their area. The reader will note Citellus parryi could have any one of the following other names; Citellus undulatus or Spermophilus undulatus. It is just as well that the arctic ground squirrel does not know how to read!

TABLE OF CONTENTS

Frontispiece. A. The arctic ground squirrel (*Citellus parryi*) is a characteristic mammal of the upland and arctic tundra. Several subspecies of this animal occur within Alaska. Unfortunately, the taxonomy of this species presently is in a confused state.

B. Mealy redpoll (*Acanthis flammea flammea*). In the subarctic one can approach the nesting birds uncommonly close. A great many of the passerine birds nest either on the ground or only a few feet above it.

A

B

INTRODUCTION

The purpose of this study is to gain information pertaining to the ecology and epidemiology of two organisms in the Tanana Valley, Alaska. One of these organisms, Coxietta burnetii, which causes the disease commonly known as Q fever, is known to have a complex epidemiology throughout vast portions of the world. Little, if anything, has been reported concerning its occurrence in arctic and subarctic areas, particularly in Alaska. The second organism, Francisella tularensis, the etiological agent of tularemia, is also known to have a broad distribution, but more is known of its occurrence in subarctic and arctic regions. In recent years various investigators have published data pertaining to tularemia organisms in Alaska. Jellison (1965A and B) has reviewed most of what is known about both organisms in Alaska.

We approached the study from two aspects. We have surveyed the literature concerned with the ecological and epidemiological history of each of the two selected organisms. Other rickettsial diseases and known arthropod-borne virus infections for which there is background evidence of endemicity in Alaska have also been reviewed. Inasmuch as most of the mammalian fauna in Alaska is of Eurasian origin and also enjoys a wide distribution across the northern portion of this continent, the literature survey will of necessity deal with at least eastern Siberia and all of Canada. The other approach was actually concerned with zoological collections in

selected areas of the Tanana Valley. Further, these animals were used as sources of serum samples, tissues, and pools of parasitic arthropods thought to be of possible public health importance. From these samples bonafide diagnostic assay has been carried out in an attempt to isolate the organisms and/or their antibodies. Eighty-five percent of our initial effort was confined to the Tanana Valley and the mountain ranges that are adjacent to it. Fifteen percent of the effort could have been expended as a whole. Equally important, we have attempted the accumulation of basic biological information concerning population densities of mammals and ectoparasites, identification of ectoparasites and their hosts, host relationships, all of which are presently poorly understood in Alaska.

I think it is only fair to state that this has indeed been a hectic year. To have organized a program of this magnitude and have all phases an integrated, functioning unit has required considerable effort and, of course, cooperation from all concerned. It is regretted we have not, as yet, terminated the microbiological assay studies. In part, the latter is due to the recent shipment of some materials from Alaska from Dr. Hufman and Mr. Molchan. Equally important, however, was the mass of material to be processed and the time lost in gaining clearance for laboratory personnel. Due to the time required for the clearance process we were unable to begin the assay work until nearly the end of the third month. It is relatively easy to procure the biological tissues, but it

takes considerable time and patience to process the material once it is in the laboratory. The laboratory phase of the program is always fraught with problems, one cannot predict with preciseness how long it will take to isolate a given etiological agent or how many hours will be spent identifying organisms that are closely related to the one in question. Enjoyable as the challenge has been, our working schedule has been too arduous and far too compact for the best in scientific effort.

PERSONNEL

The following list provides information concerning the personnel that have been associated with the project up to the present time. All operational individuals have received the necessary security clearances. The list is compiled according to the responsibility or area of performance.

Director:	Cluff E. Hopla, Professor and Chairman, Department of Zoology
Deputy Director:	Wm. O. Pruitt, Jr., Visiting Associate Professor of Zoology, University of Oklahoma
Research Scientist:	Wm. L. Jellison, U.S.P.H.S., (Ret.), Hamilton, Montana
Field Technicians:	
Edwin Bullock	University of Utah
Rayburne Goen	University of Oklahoma
Gerald Richards	Brigham Young University
Robert Richardson	University of Oklahoma
Harold Ritter	University of Oklahoma
Samuel Stoker	University of Oklahoma
Dean Stock	University of Utah

Laboratory Technicians:

Stanley Bauman	University of Oklahoma (terminated Jan. 31, 1965)
Arlene Robinson	University of Oklahoma
Donald J. Barras	University of Oklahoma

Laboratory (Glass washing):

Margaret Jervis	University of Oklahoma

Animal Caretaker:

Douglas Jones	University of Oklahoma

Secretarial Assistants:

Gilda Marie Olive	Hamilton, Montana
Mrs. Babe Strong	University of Oklahoma (not on project payroll)
Mrs. Joyce Markman	University of Oklahoma

Hourly employees: misc. duties

Nancy Adams	University of Oklahoma
Majorie Hanson	University of Oklahoma
Robin Young	University of Oklahoma
Michael Nash	University of Oklahoma

Trappers:

Dr. L. L. Hufman	Paxson Lake, Alaska
Mike Molchan	Eagle, Alaska

Literature survey: Dr. Jellison has conducted a literature survey with the aid of Mrs. Olive. In addition, he has facilities of the library at the Rocky Mountain Laboratory at his disposal. Liason has been maintained mostly by correspondence. However, Dr. Jellison was able to vist me here at the University of Oklahoma for two days during December which enabled us to discuss many of the problems relevant to the literature survey that is difficult to encompass by correspondence. Dr. Jellison has furnished the

material for two reports dealing with the literature survey and is now currently working on a host-parasite index.

Field survey: Two "advance field teams" were furnished by the Ecology and Epidemiology Branch, Dugway Proving Grounds from July 1 - July 15, 1964. Their duties were specifically to work with the hematophagous insects and/or arthropods thought to be of possible medical importance. This was necessary because it was not practicable to organize and equip personnel for two field units from this University due to the shortness of time. However, two University field parties were fully equipped and operational in the field by July 15 and remained in Alaska until at least mid-September. Unit one consisted of Stoker, Richardson, Ritter and Hopla. Unit two consisted of Stock, Bullock, Goen and Pruitt. All personnel with the exceptions of Hopla and Pruitt were in various phases of their graduate training, with Mr. Stoker being the only one not in the field of Biology.

Laboratory: Bauman, Barras, Robinson, Jervis, Jones, Professors Hopla and Larsh are responsible for this part of the investigation. Mr. Bauman, Mr. Barras and Miss Robinson all possess Master's Degrees in the area of Medical Microbiology. Mr. Bauman terminated January 31 in order to pursue graduate studies for a Ph.D. Degree elsewhere. Fortunately, Mr. Barras was available; he has developed very well and he and Miss Robinson are a compatable team. Mr. Barras has the responsibility for the tissue studies whereas Miss Robinson is in charge of the serology. Mrs. Jervis has had some college

education, a considerable amount of secretarial training, and is utilized to maintain records and is in charge of glassware preparation. Mr. Jones is an ex-serviceman and is the animal caretaker. Dr. Howard L. Larsh is a Research Professor in the Department of Microbiology and served without financial remuneration in this study. His help was deeply appreciated during the early phases of the program when I was in Alaska, and again when we were phasing Mr. Barras into the program. He helped to maintain coordination among the latoratory personnel who were learning techniques specifically confined to this program. Since my return from Alaska his contact is nominal but he is available for consultation when needed. Mrs. Joyce Markman was employed as a full time secretary beginning January 1. She has had graduate work towards a Master's Degree in Medical Entomology. Her sense of dedication and responsibility have been deeply appreciated. Miss Robin Young, while only an hourly helper, has been placed in charge of preparing ectoparasites for study purposes as well as preparing nearly all of the art work for illustrative purposes in the reports.

FIELD PROCEDURES

Collection of specimens - From the following account it is evident that greater emphasis was placed upon mammals rather than upon birds. This was thought to be a reasonable procedure inasmuch as the greater amount of information concerning the two organisms has been largely recorded from mammalian rather than avian populations.

Our collecting efforts were dual in nature; not only did we desire to collect relatively large series of animals (if possible) for medical purposes, but we also desired to obtain indices of population densities wherever possible. For the latter purpose we used a standardized plot sampling technique that Pruitt has employed successfully in many regions of Alaska.

We used folding Sherman live traps, Museum Special snap traps, Schuyler snap traps, National live traps, mist nets and shotguns. After setting up camp in a new area we set a variety of types of traps in as many habitats as we could. If a particular habitat or site produced several individuals we concentrated further efforts on that site. Sometimes a likely area was literally saturated with traps. We checked the live traps at least thrice a day (early morning, mid-afternoon, and late at night). Snap traps were visited as often as time permitted. Greater emphasis was placed upon live-trapping inasmuch as far better serum samples could be obtained from the live animals taken when such a procedure was followed. At times we encountered a species (Microtus gregalis) which was not readily captured by live-trapping but which could be readily obtained with snap-traps.

In order to obtain indices of population densities we established five standardized trap sampling plots. One of these (SUM) had been previously sampled in the mid-1950's during times of both high and low vole populations.

Standardized Sample Plots:

NEN-1: mature white spruce-birch taiga, Mile 21, Nenana Road. This plot was set with 100 Sherman live traps.

NEN-2: mature white spruce-birch taiga, Mile 21, Nenana Road. This plot was about 100 yards west of NEN-1 and was set with 50 Museum Special and 50 Schuyler traps as described by Pruitt (Jour. Mammalogy, 39(1) 1958: 157).

MAN-1: Old field, Dart property, Manley Hot Springs. This plot was set with 50 Museum Special and 50 Schuyler traps.

MAN-2: Old field, Dart property, Manley Hot Springs, about 100 yards west of MAN-1. This plot was set with 100 Sherman live traps.

SUM: Mile 3.5, Denali Highway, shrubby alpine tundra. This plot was previously trapped in 1954 and 1956, thus giving us a valuable base datum on population densities. It was again trapped with 50 Museum Special and 50 Schuyler traps.

Once the mammals were caught, they were placed in an appropriate size cloth bag, brought into the field laboratory, which consisted of an 8 x 10 white wall tent, lightly anesthetized and blood samples obtained by cardiac puncture. Earlier in the summer, we experimented with another well-known method of obtaining blood from a cut in the skin axillary region then snipping a blood vessel. Subarctic animals tend to have greater quantities of fat in this region then in desert regions where this technique has been successful. We found the cardiac route to be far more successful. The blood samples were placed in a "cool box" which consisted of a

pit dug in the ground until permafrost was reached, usually at a depth of 2 1/2 feet. A "Blazo" box was placed in the pit, and the blood samples stored therein, at a temperature of approximately 47° F. The clots were ringed after two to four hours and allowed to contract overnight after which the serum was harvested. The serum was pooled, the pools maximally consisting of five specimens of the same species in the same habitat. The ectoparasites were collected from each animal after securing the blood sample and were placed in separate vials in order that accurate data concerning host association and infestation rates could be obtained. For such groups as the Siphonaptera, data on these phenomena are sorely lacking, particularly in the subarctic regions. After the ecto-parasites had been secured the animal was autopsied and portions of the spleen, liver, heart and lungs removed. These tissue samples were pooled in the same fashion as that indicated for the serum samples. At this time the tubes containing the serum, the blood clots, and the tissues were sealed by means of an acetylene torch, allowed to cool, and stored in a liquid nitrogen chest.

Liquid nitrogen was used as a refrigerant because of the difficulty in obtaining a reliable source of dry ice in the Fair-banks region and because of the extremely high cost of dry ice there. We found that the type liquid nitrogen chest we used did not need recharging more frequently than once a month.

Subarctic mammals usually have only a low density of ecto-parasites such as sucking lice (Anoplura) and fleas (Siphonaptera).

In view of the paucity of knowledge concerning these creatures, particularly in the central portion of Alaska, it was decided to retain most of these specimens for identification studies. However, when nests of the rodents and birds could be secured, where a reasonable number of ectoparasites could be harvested, the specimens were pooled for biological assay.

The birds were obtained by mistnetting and by shooting. Mistnetting was preferred over shooting as we obtained better blood samples from the netted birds. The blood was obtained by puncture of a neck vein; this method proved better than either cardiac or wing vein puncture. The handling of the tissue samples and ectoparasites was essentially the same as that of the mammals.

All supplies for storage of blood and tissue samples consisted of various sizes of Pyrex test tubes which were cotton stoppered, autoclaved, and wrapped in air-tight containers for shipment to the field crews. The tissues still in the nitrogen chests were shipped to the University of Oklahoma where they were stored in low temperature cabinets.

Two hundred and fifty-four pools of mosquitoes, belonging for the most part, to the genus _Aedes_, with a smaller proportion of the genus _Culiseta_, were obtained by the two Dugway teams. This represents a total of 9,788 specimens. At the time the mosquitoes were collected, they were stored in tubes containing buffered glycerin and were then sealed and stored in the nitrogen chests as previously

indicated for the tissue samples. Some of the fleas were frozen in sealed tubes, while the few pools of ticks were retained alive in order that feeding experiments could be conducted with them later in the year.

All tubes were labeled on the outside, and before sealing, a small paper tag with the collection number was inserted on the inside in an effort to preclude loss of identification. We have found no substance entirely satisfactory for labeling the Pyrex tubing on the outside in preparation for subsequent storage in liquid nitrogen although standard hospital adhesive tape has proved to be better than various other materials thus far examined.

ECOLOGY

Alaska is the biological gateway to North America. In times past a considerable part of the recent North American mammal fauna has surged back and forth through this gateway. Some species have travelled eastward, some westward. Those species that travelled eastward have had opened before them two major pathways, the tundra route and the taiga route. Interestingly enough, what is now known as the Tanana Valley is thought by many to have formed part of the "refugium" through which the various species of animals passed during the glacial periods of the Pleistocene.

The tundra route was open only to a select few species, those that possessed certain critical adaptations that enabled them to ecize this peculiarly restrictive environment.

The taiga route, while still selective, was less demanding than the tundra route. Consequently, the species using it were less restricted in their ecological tolerances. Moreover, the taiga route, once entered on by a species, was potentially of vaster extent than the tundra route. Taiga invaders, once they entered the North American taiga, found spread before them a habitat that stretched virtually enchanged for some 3,900 miles, from western Alaska to Newfoundland and which encompassed 17 percent of the land area of the continent. In addition to the great boreal forest across the top of the continent, taiga invaders were able to follow similar habitats in mountain taiga far to the south in the Rockies and the Appalachians, thus flanking the great grasslands of the mid-continent region. Consequently Alaska is the zoogeographic key to North America, and the taiga of the Tanana and Yukon valleys, being one of the largest blocks of taiga in Alaska, are the keys to understanding Alaska.

In the undisturbed taiga of the Tanana Valley the most common mammal is the redbacked vole (Clethrionomys). It is also one of the basic species in the food web, turning the taiga vegetation into animal protein which higher trophic levels can utilize. Other producers, of somewhat less numerical importance, are the red squirrel (Tamiasciurus), the snowshoe hare (Lepus), and the moose (Alces).

Upon this trophic base is built the superstructure of the

taiga food web, the carnivores and scavengers. In the Tanana Valley the main carnivores are the weasels (Mustela), the marten (Martes), the lynx (Lynx), and the wolf (Canis). Another mammal that is technically a carnivore but ecologically a scavenger is the black bear (Ursus).

The taiga of interior Alaska is unique among other major regions of this ecosystem in northern North America in that projecting up through it are mountains high enough to be devoid of taiga vegetation (Fig. 1 - 5). Consequently the alpine aspects of the taiga must be considered (Fig. 6). I look on these alpine areas as variants of taiga because of their relatively limited extent and because of their complex interdigitation with the more typical lowland taiga. To be sure, there are some typical mountain mammals in the Alaska hill country, the marmots (Marmota), the ground squirrels (Citellus), the white sheep (Ovis) and the pika (Ochotona). But the mountains in the interior of Alaska do not consist of regions extensive enough for the presence of a true mountain fauna - such as that found in the mountains and high plateaus of Asia. Moreover, the Alaska alpine fauna is diluted by taiga species that flood upwards from lower elevations. Among these are species of Clethrionomys, Microtus, Lepus, Alces, Mustela, Lynx, Canis and Sorex.

To complicate the ecological picture still more, the taiga of interior Alaska has suffered greatly from man's activities.

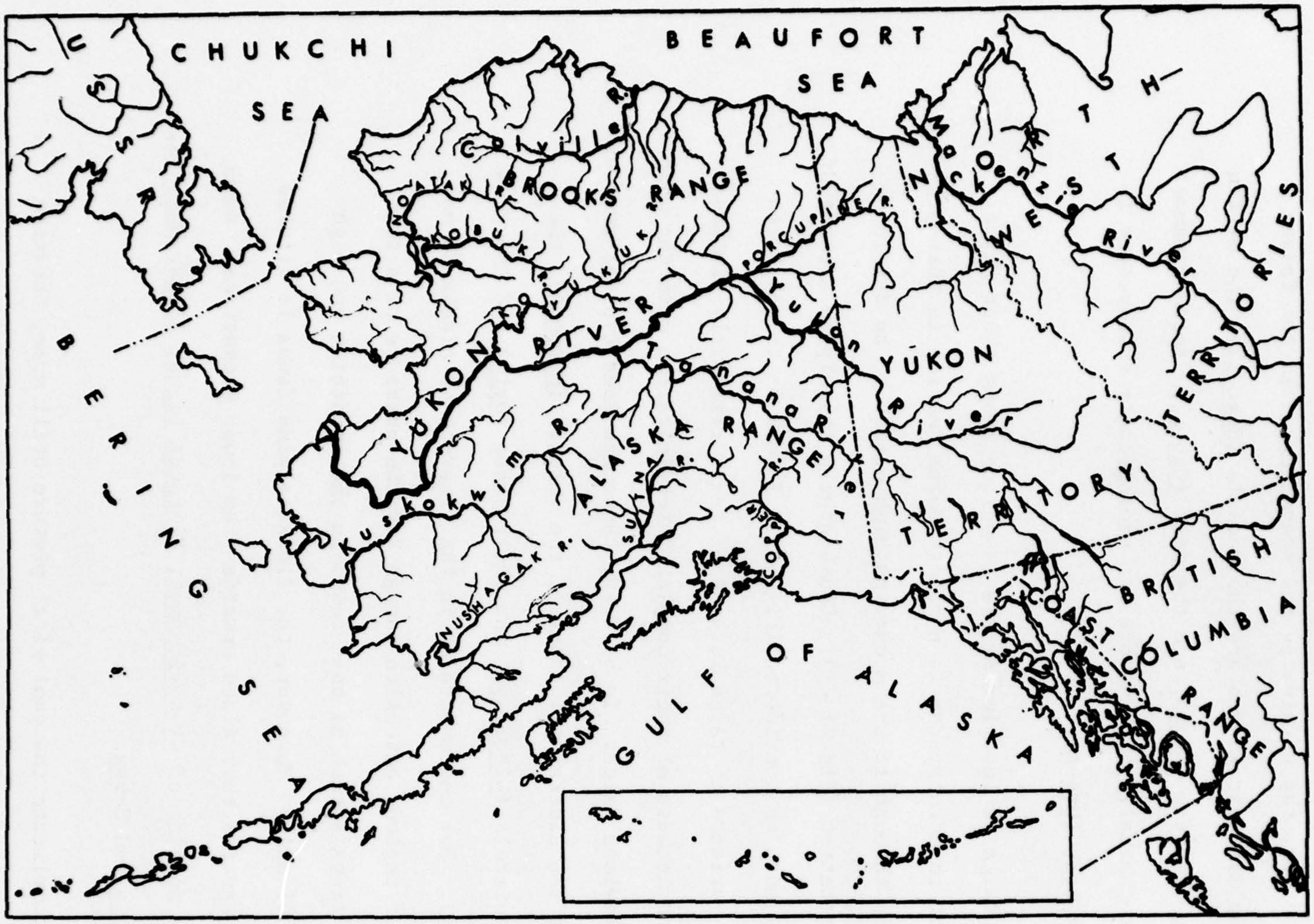


Figure 2. Principal drainage systems in Alaska; with the exception of the Colville River and its tributaries, most of the rivers flow approximately in the west southwesterly direction.

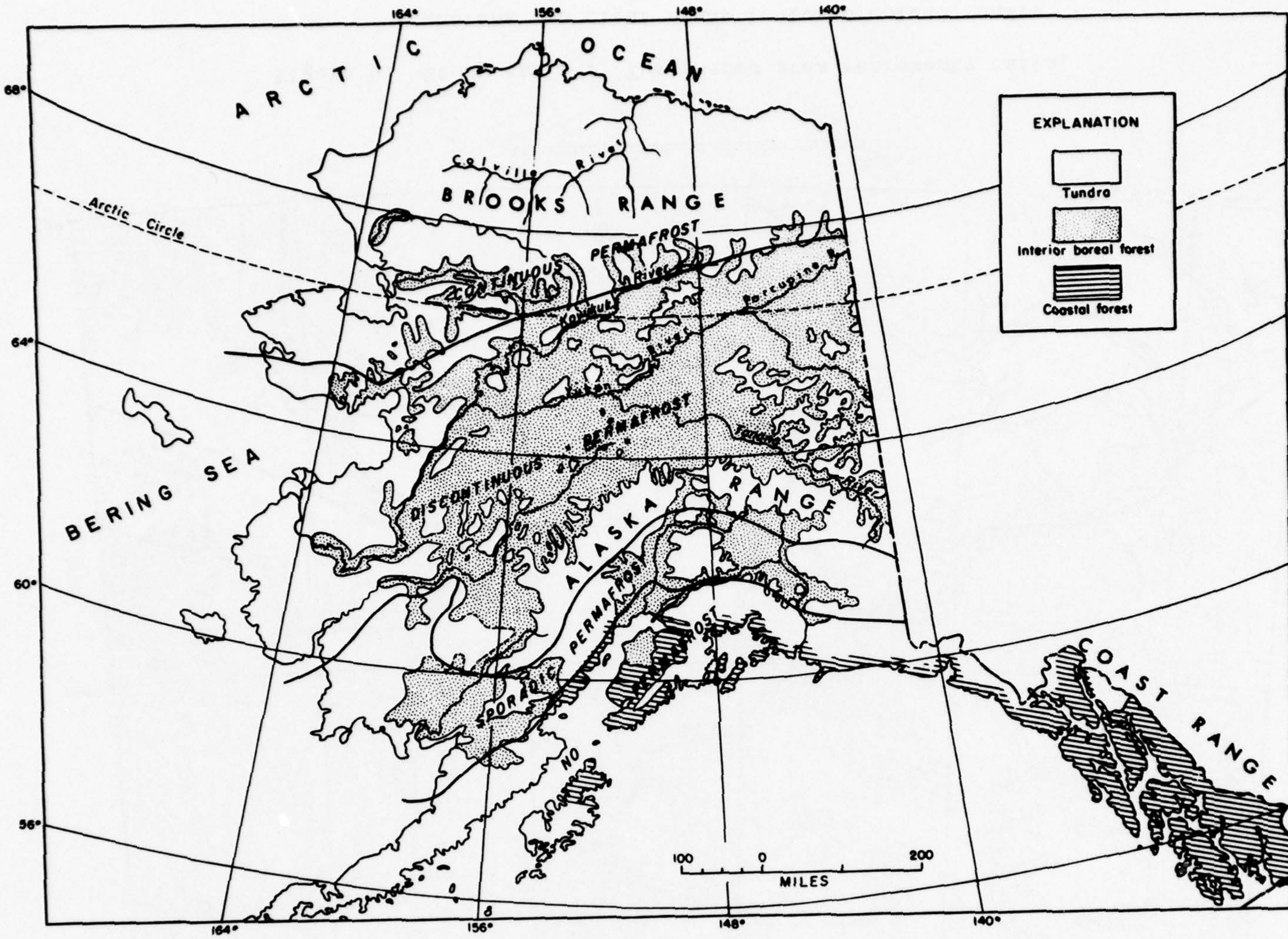


Figure 1. The distribution of treeless and forested areas in Alaska. The treeless areas consist mainly of tundra, but also include glaciers and exposed bedrock.

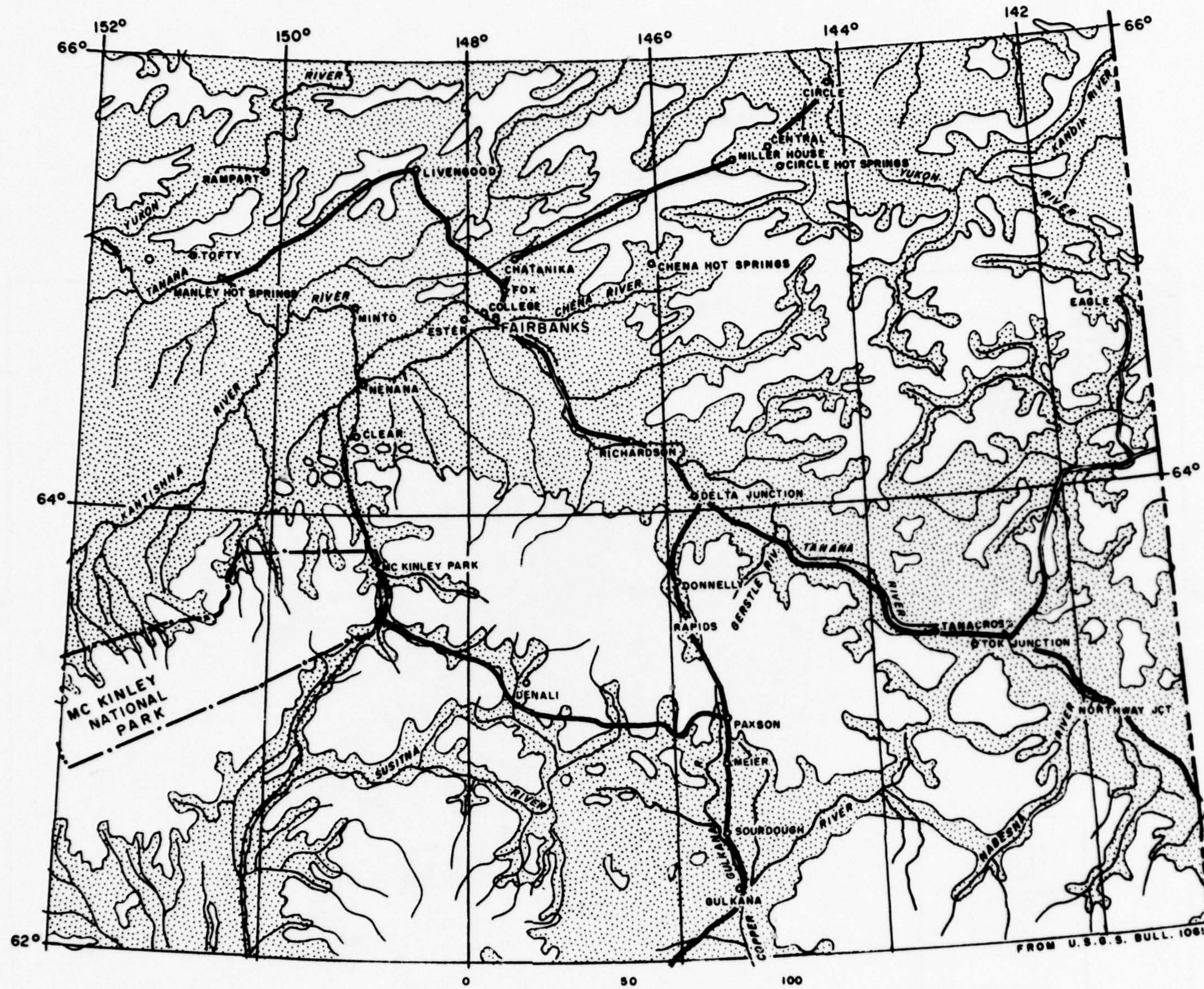


Figure 4. Study region. The shaded area represents taiga, whereas the clear areas indicate upland tundra. All major highways in Alaska are included.

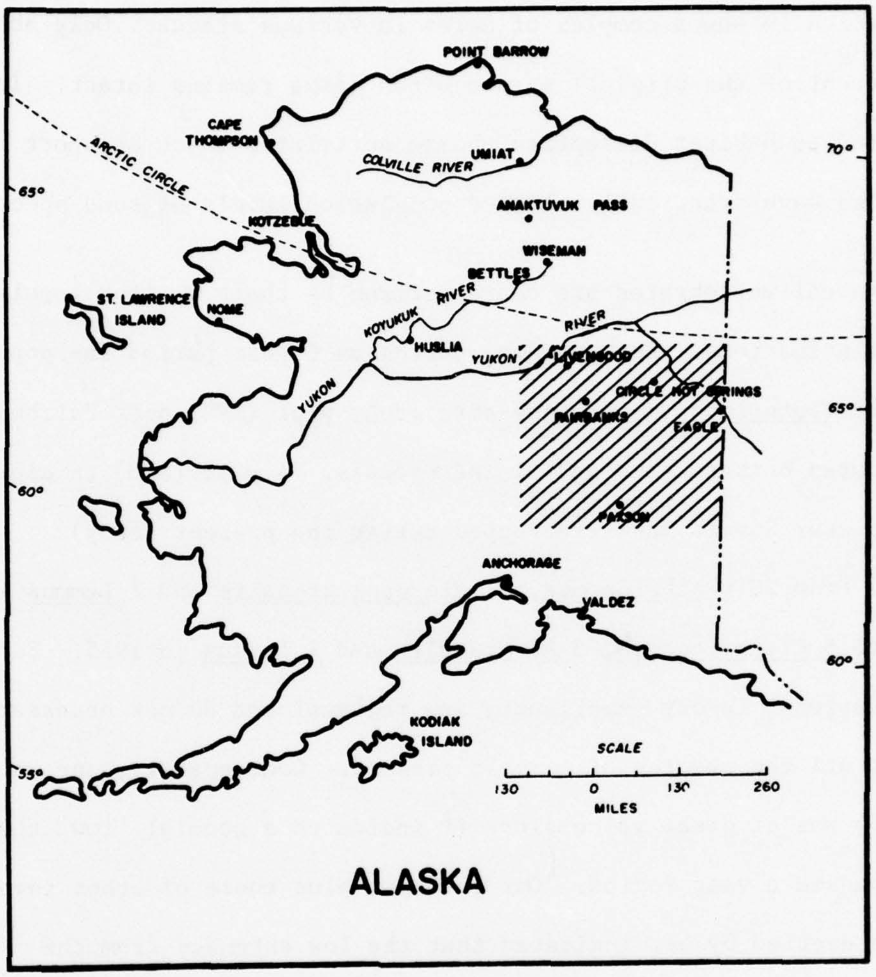


Figure 3. Outline map of Alaska showing the relationship of the study region to the rest of the state.

Fires, mining, "stick-farming" and other man-oriented influences have thoroughly disrupted the original ecosystem so that it bears only slight resemblance to what it originally must have been. The vegetation is now a complex of seres in various stages. Only about 20 percent of the original spruce-birch taiga remains intact. In addition to habitat disruption, human activities (such as sport hunting) have drastically altered population levels of some species.

Boreal vertebrates are characterized by their violent population fluctuations. For example, during an 8-year period the population of *Clethrionomys* on a one-acre study plot (SPR) near Fairbanks fluctuated between zero and 31 individuals. A plot (SUM) in alpine tundra near Summit Lake (retrapped during the present study) varied from 28 *Clethrionomys*, 21 *Microtus gregalis* and 7 *Lemmus* in 1954 to 5 *Clethrionomys*, 5 *M. gregalis* and 1 *Lemmus* in 1955. Such fluctuations, in our experience, are regional and do not necessarily affect all the species of mammals present. Consequently, our sampling in 1964 was of great value since it indicated a general "low" that encompassed a vast region. Our results, plus those of other investigators queried by us, indicated that the low extended from the Brooks Range through the Alaska Range. The only place in Alaska known to have had a "high" during the summer of 1964 was Umiat (on the "Arctic Slope"). As an indication of the magnitude of the "low" consider the 1964 sampling of the SUM plot: 1 *Clethrionomys*, 2 *M. gregalis* and 1 *Lemmus*.

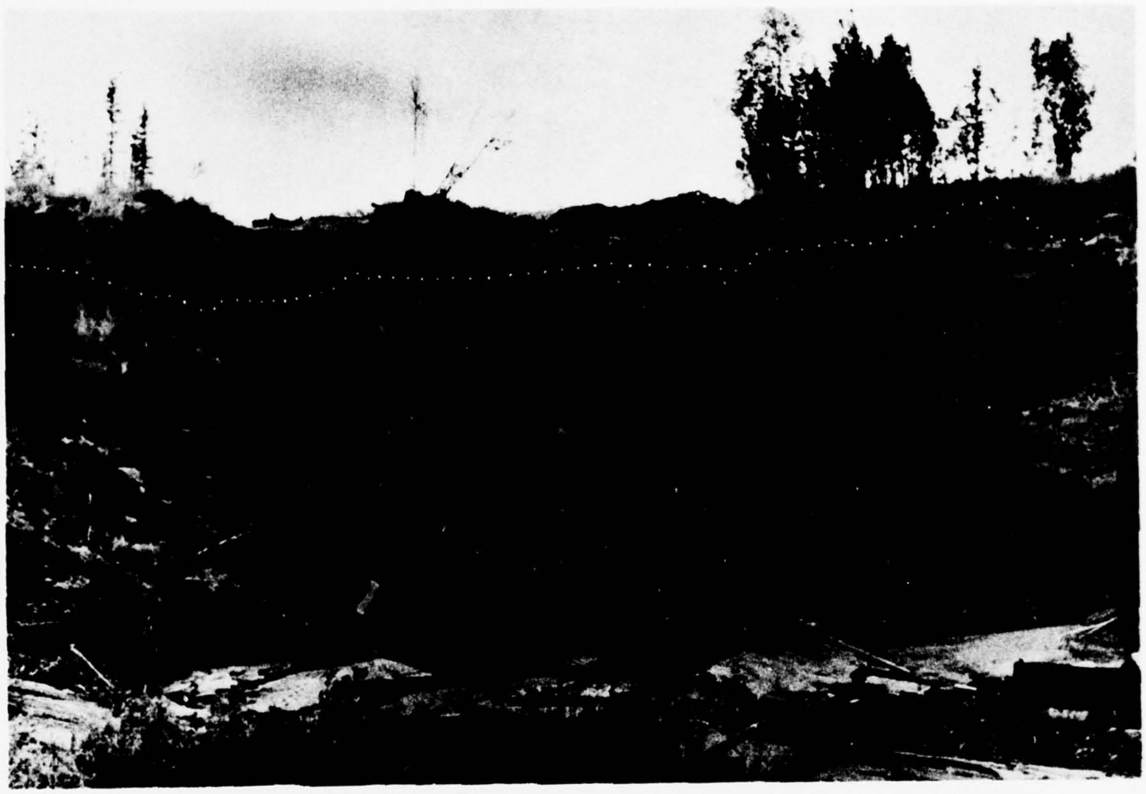


Figure 5. Throughout much of the Tanana Valley, permafrost (dotted line) lies at a depth of from 2 to 3 feet below the surface of the ground. In this example the permafrost continues down to bedrock.

DESCRIPTION OF SITES

Inasmuch as our study was for, the most part, confined to the Tanana Valley, some consideration of the climatological data that has been collected over the years by governmental agencies should be indicated. The Fairbanks environs is typical of the taiga; the weather data should be representative. The climate is characterized as a cold continental, i.e., short, warm summers and long, cold winters. A mean annual temperature of 26.1° F., with extremes of 99° F. and -66° F. have been reported for this locality. The mean annual precipitation is 11.7 inches, 60 percent of which falls during the period from May to September as rain. The mean annual snowfall is 67 inches. Temperatures in the upland tundra would vary considerably from this but reliable dataare not available.

The principle drainage system (Fig. 2) of the Tanana Valley centers around the Tanana River which in turn empties into the Yukon River. Much of the terrain in the Tanana Valley is low, without the precipitous mountains which are known further to the south. Only as one approaches the southern limits of this valley are high mountains encountered and here the flanks of the Alaska Range essentially form the southern boundary.

Buckley and Libby (1957) did an extensive study. Table 1 is taken from their study and reveals much of the different amounts and/or kinds of ecological types of habitat.

Table I. Abundance of Major Environmental Types in the Study Area.

Type	Number of Plots	Percent of Total Plots
Forest	1,281	66.61
Tall Brush	140	7.28
Dwarf Brush	259	13.47
Herb	137	7.12
Aquatic	53	2.76
Bare	53	2.76
Total	1,923	100.00

According to Buckley and Libby (op. cit.) approximately two-thirds of their study area was composed of land either now supporting tree growth or has supported tree growth in the past but is now devoid of trees because of the fires. It seems valid to assume that this actually is forest area because these burned areas will again support tree growth in the future. In certain areas tree growth is extremely sparse within a forested region and for convenience, the forested regions can be divided into three broad categories; namely, coniferous forests, deciduous forests and mixed forests.

The coniferous forest types are spruce (mostly white spruce, Pica glauca), muskeg (sparse black spruce, Picea mariana), spruce-larch, (usually black spruce and larch, Larax laricina) and larch. Pure stands of larch are seldom encountered and consist of small stands. The coniferous forests usually have a dense cover of various species of mosses, far more so than that of the other groups.

The deciduous forests are white birch (Betula papyrifera), aspen (Populus tremuloides), cottonwood (Populus balsamifera), and

various admixtures of these species.

The mixed forests are composed of all possible combinations of the foregoing types. For the most part, however, white spruce-white birch, aspen-white spruce, cottonwood-white spruce and aspen-white spruce-white birch predominate.

In addition to the species of trees indicated above, various species of willow (Salix sp.), alders (Anlus incana), dwarf birch (Betula glandulosa), blueberries (Vaccinium uliginosum), Labrador tea (Ledum groenlandicum), horsetail (Equisetum), "nigger-heads" (Eriophorium vaginatium), and cotton grass (Eriophorium scheuchzeri), high-bush cranberry (Viburnum edule), and the low-bush cranberry (Vaccinium vitis-idaea) frequently form a dense ground cover. The common forbs are fireweed, (Epilobium angustifolium), twin-flower (Linnaea), and wintergreen (Pyrola sp.).

Fairbanks Region

Fort Wainwright:

Birch Hill - North-facing slope and pond-side beyond. Vegetation mostly tall grasses, scattered aspen, birch and white spruce.

River Lab - A heavily-disturbed area on the flood-plain of the Chena River (Fig. 9). Vegetation mostly young Populus balsamifera and aspen; ground cover of sparse to dense grasses and forbs.

Sheep Creek Road, near College - Stream Valley and adjacent upland. Vegetation heavily disturbed, black spruce muskeg in valley, white-spruce, aspen and birch upland.

Mile 21, Nenana Road - Steep hillsides of Nenana Ridge. Vegetation: (1) disturbed upland white spruce-birch forest (2) undisturbed mature spruce-birch taiga.

Bonanza Creek Experimental Forest - Upland and moderate slopes of Nenana Ridge. Vegetation: (1) moderately disturbed white spruce-birch forest, (2) undisturbed mature white spruce-birch forest.

Nordale Woods - Flat, sandy flood plain of Chena Slough. This region encompassed the SPR plot mentioned above. The plot environs were lumbered in 1961. Vegetation: moderately to severely disturbed white spruce-birch forests.

Tanana Hills - White Mountains Region

Eagle Summit - This site is part of an extensive region of alpine tundra where the Steese Highway crests the White Mountains. The topography is rolling to steep. The vegetation is sedge-grass-lichen mat with many areas of dense low shrubs of willow and dwarf birch. Solifluction phenomena, such as rock stripes, sorted and nonsorted stone nets and nonsorted steps are common.

Miller House - Rolling to steep, rounded mountains. Vegetation: severely disturbed white spruce and black spruce forests. This region has been heavily utilized by white man for some 50 years and little remains of the original vegetation.

North-facing slopes support stunted black spruce with dense and thick moss-Ledum ground cover, while south-facing slopes may have small aspens, willows and grasses or even be virtually bare. The steep-walled valley floors support aspen and willows.

Circle Hot Springs - Flat lowlands and low, rolling hills. Vegetation: moderately to severely disturbed white spruce-birch forest.

Livengood Region

This region has also suffered severely at the hands of man for some 50 years. Vegetation: aspen, willows, some birch, all young stages recovering from fires. The Livengood Airport site was the bulldozed berm adjacent to the strip and the grassy edges of the strip itself.

Manley Hot Springs Region

This entire area has also experienced heavy human utilization for some 50 years. The topography is rolling hills and ridges adjacent to the floodplain of the Tanana River. Vegetation of the upland is primarily aspen with some birch. The river floodplain is spruce, aspen and birch. We also sampled plots in a weedy field surrounded by aspen-birch upland. A distinctive feature of this region are the hot springs. The warm seepages create localized habitats remarkable for their dense, lush vegetation.

Paxson Lake Region

Hufman's Camp, Mile 179 Richardson Highway - Paxson Lake is a long, deep finger lake surrounded by steep hills and mountains. The vegetation is moderately to severely disturbed subalpine white spruce forest on the slopes above the lake, giving way on the ridge tops and mountains to alpine tundra. Along the roads, lake shore and about habitations there are tall grasses and weeds.

Denali Highway - Shortly after it leaves the Richardson Highway at Paxson Lodge, the Denali Highway climbs through a narrow belt of forest-tundra and then traverses an extensive alpine tundra region. The topography varies from rolling to pot-and-kettle to moraine and finally to steep, rocky mountain slopes. Vegetation is an extremely complex shrubby alpine tundra of low willows, alders, dwarf birch and krumholz spruce, underlain by ericaceous plants and many lichens and mosses (Fig. 6). The principle factor governing plant (and animal) distribution appears to be snow cover. We sampled several sites, including the SUM plot (Mile 3.5) and an interesting snowbed at Mile 10. A discussion of these sites will be found under the section on *Microtus gregalis*.

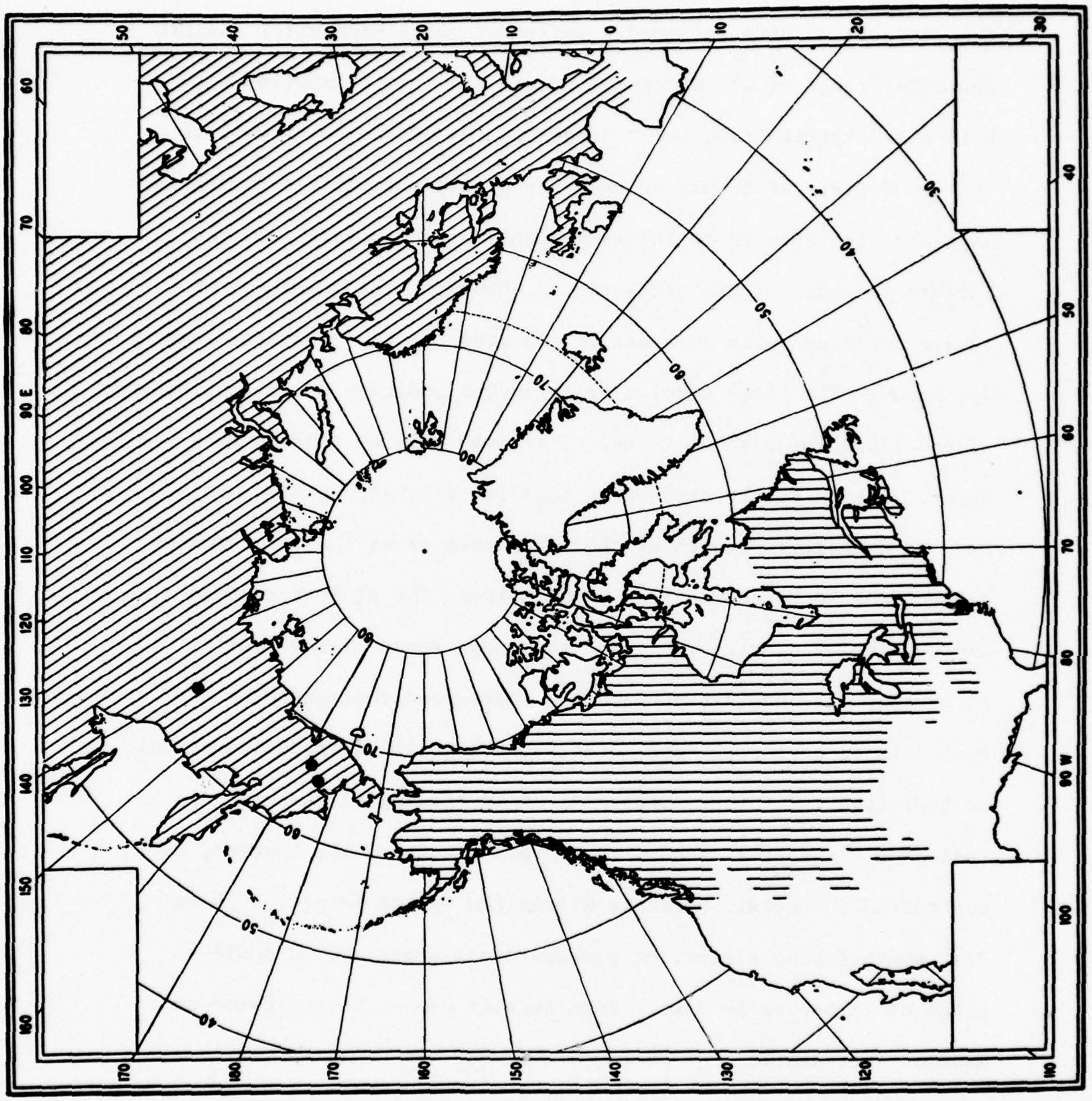
MAMMALS

The following discussion and listing considers all the mammals found within a radius of 100 miles of Fairbanks, regardless of whether we actually took specimens of them or not. We believe that an understanding of the total mammalian fauna of the region is necessary to an understanding of the zoonotic picture, both

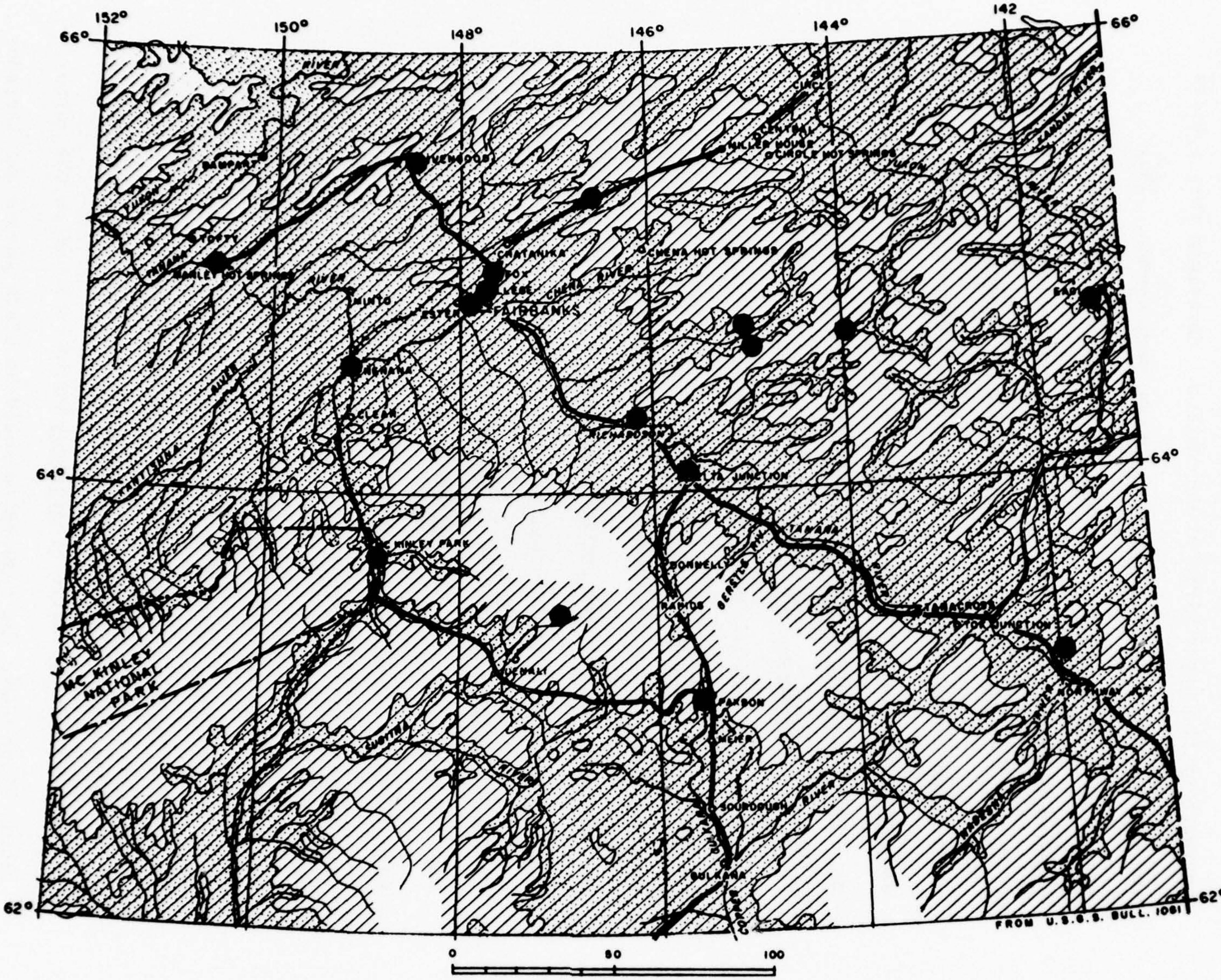
actual and potential. We also believe that this understanding is enhanced by a discussion of the total range of the species concerned. Consequently we have included a series of range maps which delimit the total range of the species, and, in the case of species with Holarctic distribution, their ranges in the Old World as well as the New World. It should be understood that the small-scale range maps show the borders of the ranges only approximately. On the large-scale maps of the study region, however, the limits of the ranges are drawn with more detail and greater accuracy where they are known. The black circles or triangles indicate actual collection sites of specimens known to us. There may well be (and in many cases, most certainly are) other locality records; we have not made an exhaustive search of the literature or of the large museum collections in North America. Nonetheless, the plotted records and the shaded overlay indicate the known range of the species concerned. It should be thoroughly understood that on a map of even this large a scale the detailed ecological distribution cannot be indicated. In other words, our basic shading on the maps indicates taiga or spruce forest. Some species will, however, be restricted to certain habitats within the spruce forest, such as dry, south-facing slopes, or perhaps dense grass around small ponds or in beaver meadows. Such details cannot be indicated on maps of this scale.

Annotated List of Species:

Sorex cinereus (Maps 1, 2) - The masked shrew is found in virtually



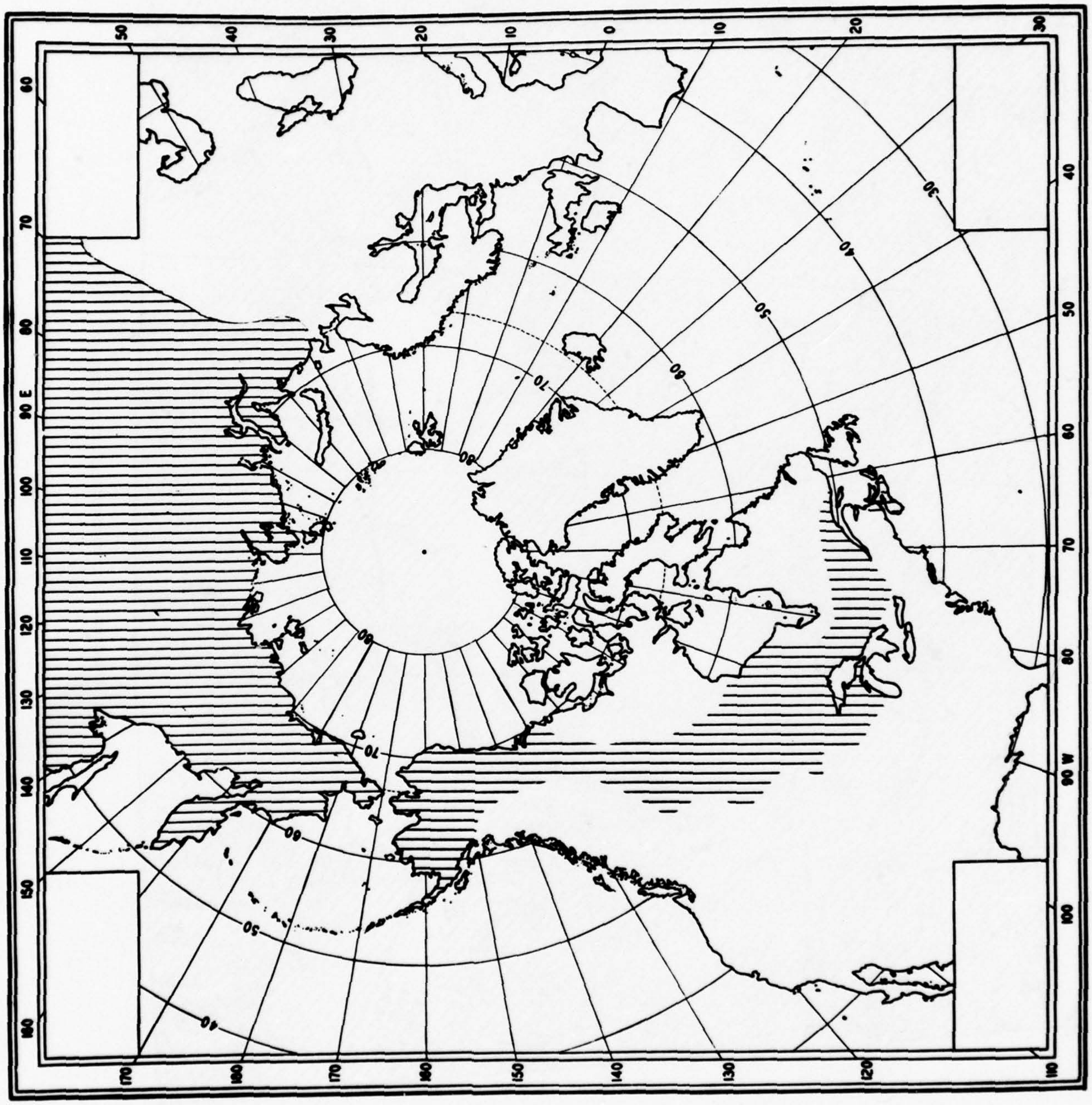
Map 1. Distribution of Sorex cinereus in North America; Asia (dots); and S. caecutiens in Asia.



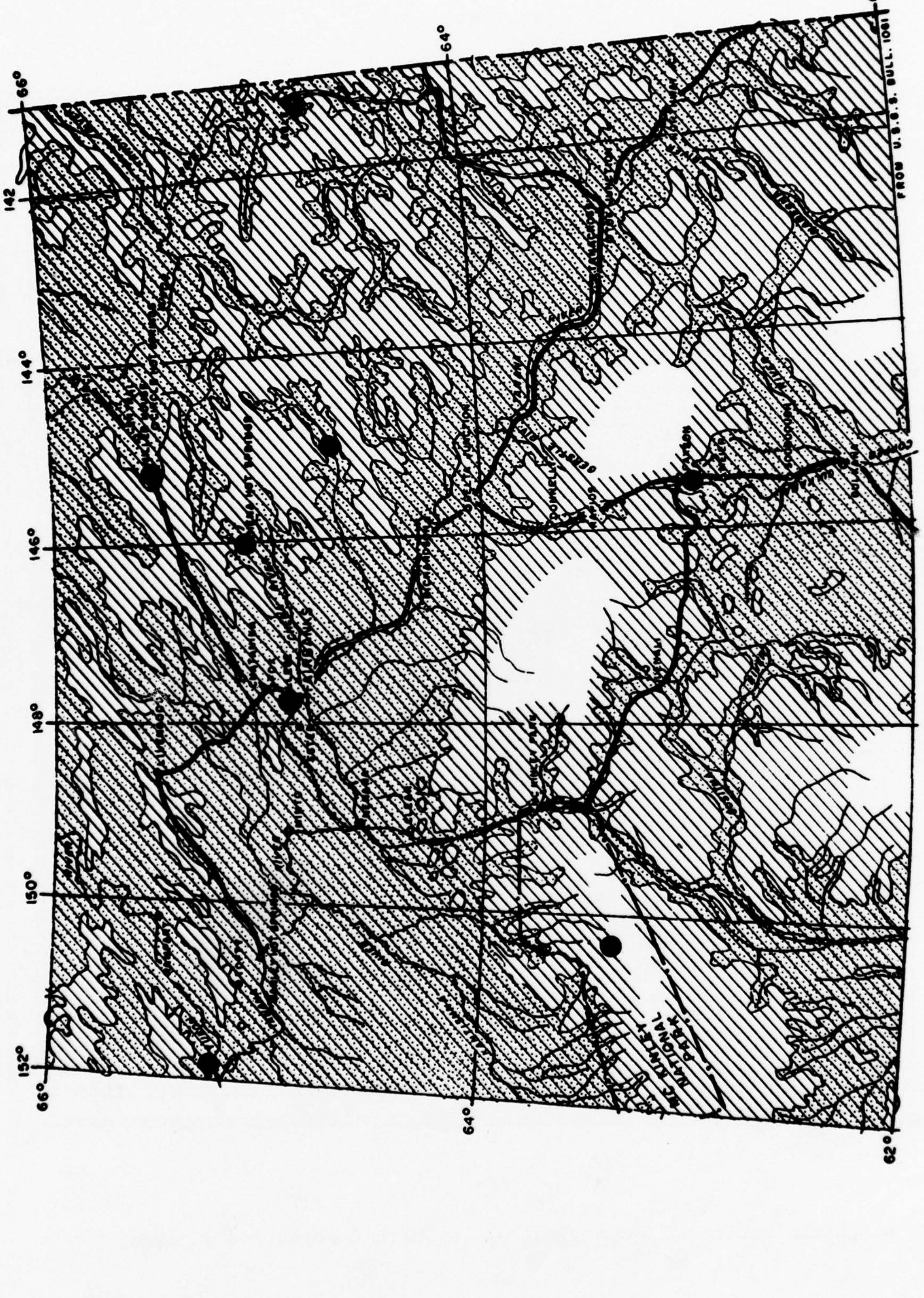
Map 2. Occurrence of Sorex cinereus in the study region.

all of our study region with the exception of the higher areas approaching the upper limit of vegetation. Sometimes this species and the related Sorex arcticus may become very common. Their populations appear to undergo rather violent fluctuations; frequently these fluctuations are in inverse density relationship to those of the voles. Shrews are primarily insect and invertebrate-eaters, but in the Subarctic they will feed on plant material, such as Betula seeds which they encounter in their snow tunnels. Van den Brink (1953) proposed that this species be synonymized with the Old World S. caecutiens. The proposal has never been adequately tested by monographic revision. Stroganov, (1957), on the other hand, separated S. cinereus and S. caecutiens by listing them sympatrically in eastern Siberia. We believe that adequate data are not available at present to resolve this question. For more complete understanding of this problem we have designated the ranges of Sorex cinereus and S. caecutiens (sensu strictu) on the map and have indicated by dots the localities from which Stroganov identified S. cinereus in eastern Siberia.

Sorex arcticus (Maps 3, 4) - The arctic shrew is also found in virtually all of our study region with the same exceptions as the previous species. In general, S. arcticus is found in more "boreal" situations than either S. cinereus or S. vagrans. Thus, S. cinereus may be found on the south-facing slopes in mature spruce-birch forest while S. arcticus would be found on the north-facing slope where the vegetation would be black spruce and Labrador



Map 3. Distribution of Sorex arcticus in North America and Eurasia.

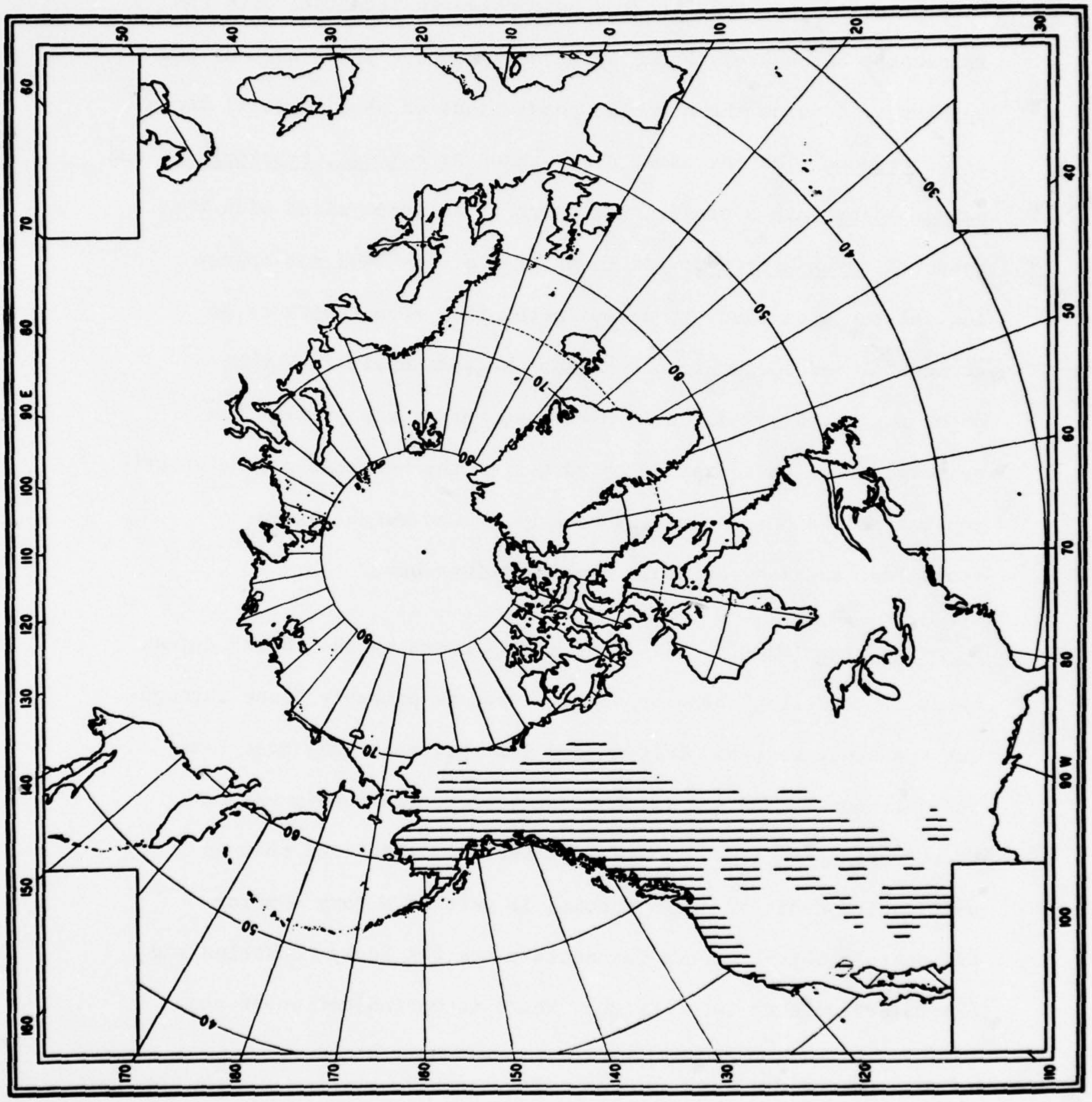


Map 4. Occurrence of Sorex arcticus in the study region.

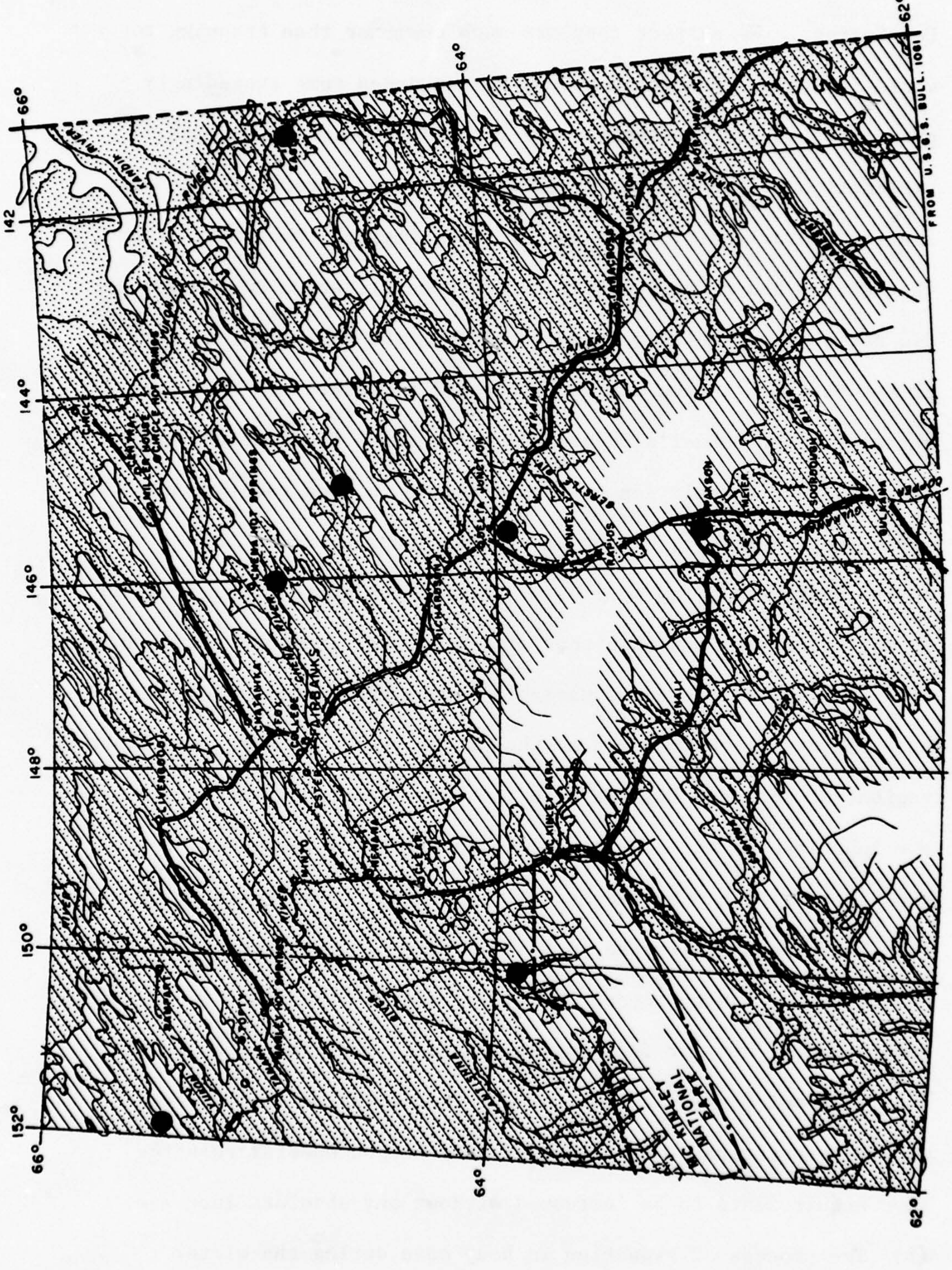
tea and the permafrost would be close to the surface. Many authors have proposed that this species be considered identical with the Palearctic Rassenkreis known by several names. The consensus now appears to combine the northern populations of what is still known as S. araneus plus the named demes known as buxtoni, schnitnikovi and sanguinidens into a single species which is synonymized with the Nearctic Sorex arcticus. At first glance this does not appear logical but upon study it agrees with other recent work on an ecological and zoogeographic basis. We personally feel that a major monographic revision is necessary before the problem can be solved. We have mapped the ranges of the Nearctic and Palearctic populations as one, primarily because of the weight given to ecological and zoogeographic considerations here.

Sorex vagrans (Maps 5, 6) - This shrew (known by the "book" common names of wandering shrew or dusky shrew) is probably found throughout the study region. Only a very few specimens have ever been taken in our region and its habitat preferences remain unknown. Pruitt has taken it only at Paxson Lake (in 1953) and then in edificarian habitat. This species is part of a very complex Rassenkreis which extends far south along the Rocky Mountains and Sierra Nevada even into Mexico. There is no indication of any identity with an Old World species.

Microsorex hoyi (Maps 7, 8) - The pigmy shrew is rarely taken in traps. Its range is deduced from a very few, widely scattered specimens in our study region. Pruitt has taken several in the

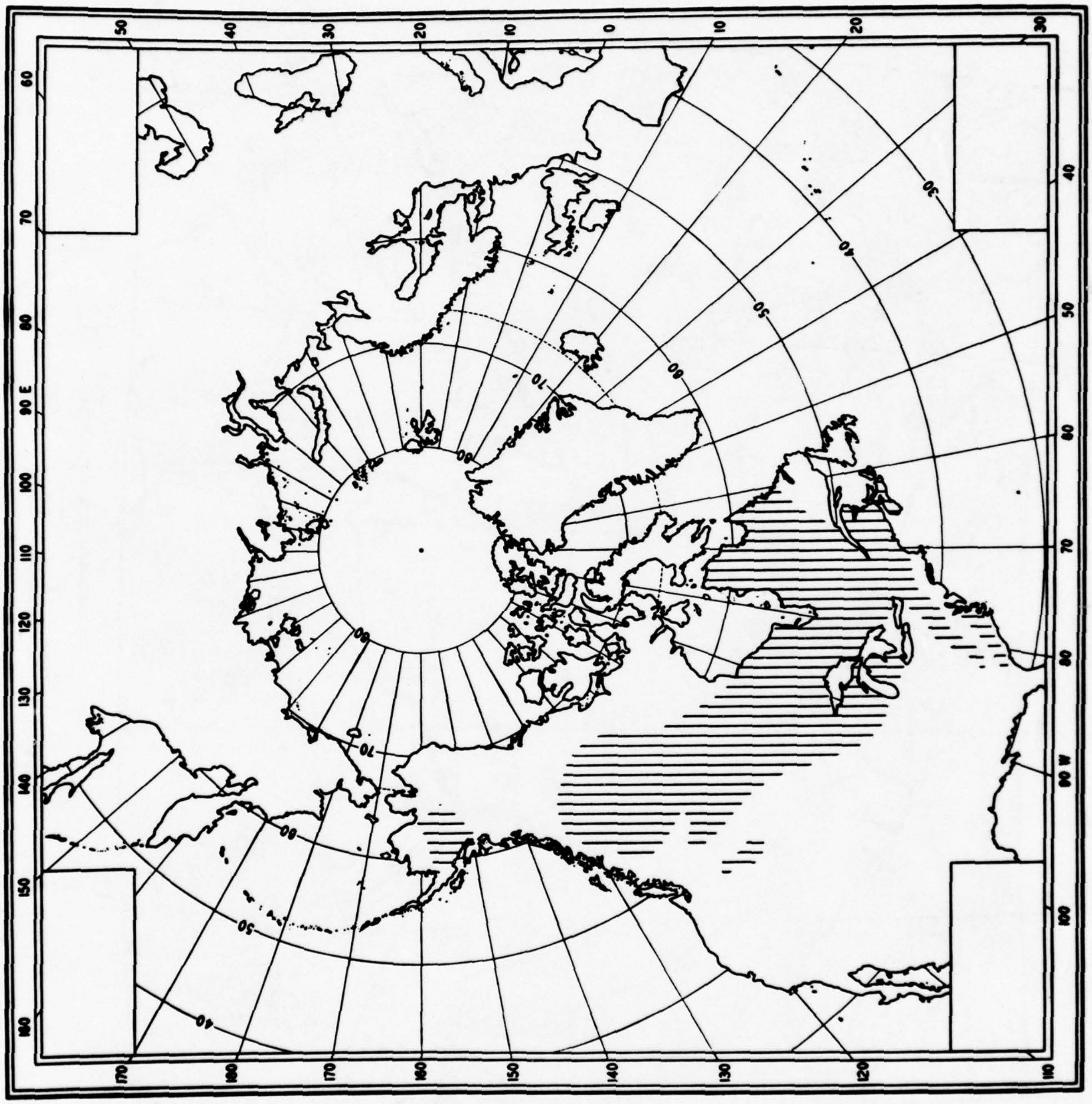


Map 5. Distribution of Sorex vagrans.

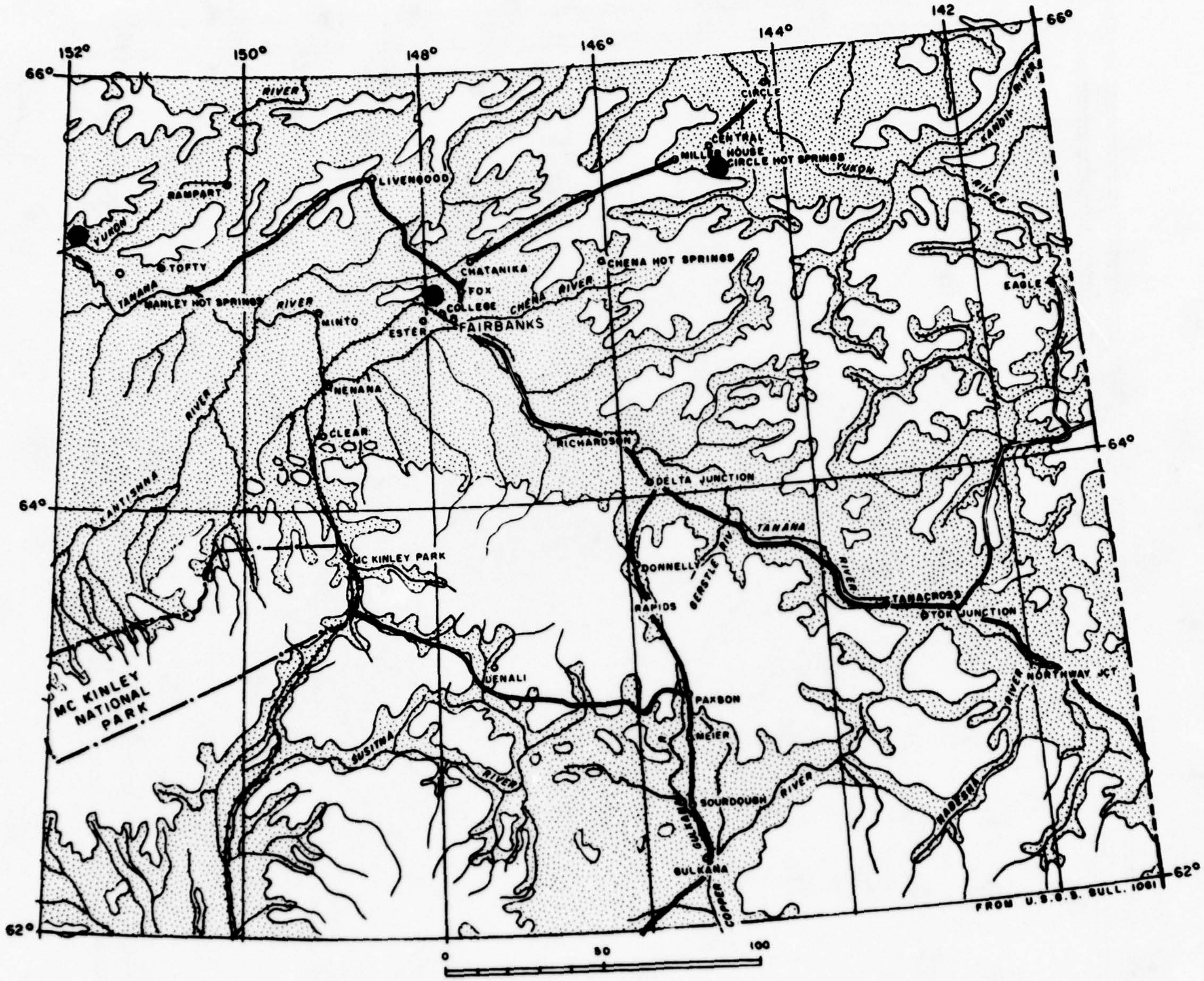


Map 6. Occurrence of Sorex vagrans in the study region.

Fairbanks region and Hopla has taken several specimens at Circle Hot Springs. We suspect they are much commoner than trapping records would indicate. Mezhzerin (1964) has advanced some exceedingly provocative ideas in his study of Dehnel's Phenomenon and its explanation. Although he worked with Eurasian shrews his findings are particularly applicable to our study region. Mezhzherin found that shrews had no very distinct food specialization and that they did not show any relation between body weight and amount of food or between food intake and environmental temperature. Since many shrews exhibit Dehnel's Phenomenon or seasonal fluctuations in mass he found correlation between decrease in food requirements and reduction in body weight in winter. He also found that representatives of any species of shrews from northern regions had a smaller body weight than that of individuals from the south, and that body weight decreased markedly during the winter; the minimum occurred during the coldest months of the year. He also found that regions of northern Eurasia with the lowest winter temperatures are inhabited by the smallest representatives of the genus Sorex. From these findings he reached the following conclusions: (1) The constant decrease in size of Sorex as one progresses northward is due to the necessity for reducing absolute food requirements, not for food specialization. (2) The exceptionally small size of certain shrews is due to adaptation to very low winter temperatures. Reduction of body weight enables relative food requirements to be increased without any absolute increase. (3) The process of reduction in body mass during the winter



Map 7. Distribution of <u>Microsorex hoyi</u>.



Map 8. Occurrence of <u>Microsorex hoyi</u> in the study region.

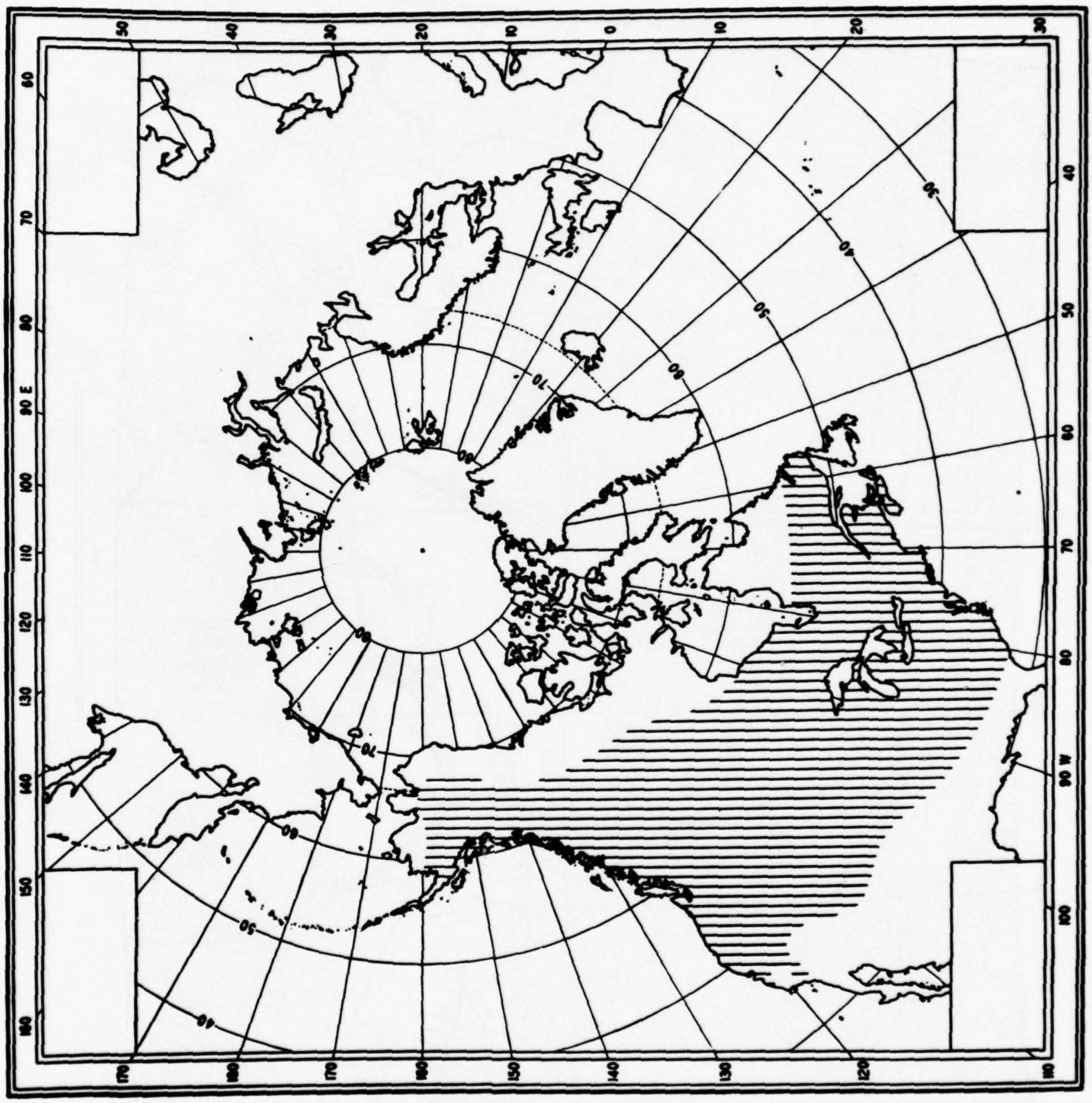
includes skull size, inhibition of endocrine activity, reduction in volume and weight of the brain and an increase in number of hairs per unit of surface. (4) Relatively large shrews cannot inhabit areas with a January mean temperature below -30° C. because their food requirements, while relatively small, are actually large in absolute units. (5) An obstacle to the westward expansion (in Siberia) of small species of Sorex is formed by the relatively high winter temperatures. They are at a disadvantage in relation to the larger species. (6) The regions of northeastern Asia and northern North America with the lowest winter temperatures may be considered the center from which the smallest forms of shrews in existence originated (with the exception of one species of Sorex).

These findings and the conclusions drawn therefrom have considerable importance. Not only do they cause re-evaluation of some cherished concepts but also because our study region is one of those few regions in North America that might fit the requirements of a center of distribution for the tiny shrews (see Rayner 1961). Mezhzherin's findings do not invalidate Bergmann's Rule. They only point up the necessity of really understanding the microhabitat of the species. Thus my work on bioclimates of shrews in the taiga (Pruitt 1957) affords a logical explanation for Mezhzherin's conclusions. Microsorex hoyi is generally considered the smallest of the North American shrews. These facts may be of potential importance in any zoonosis that might occur in shrews of our study region.

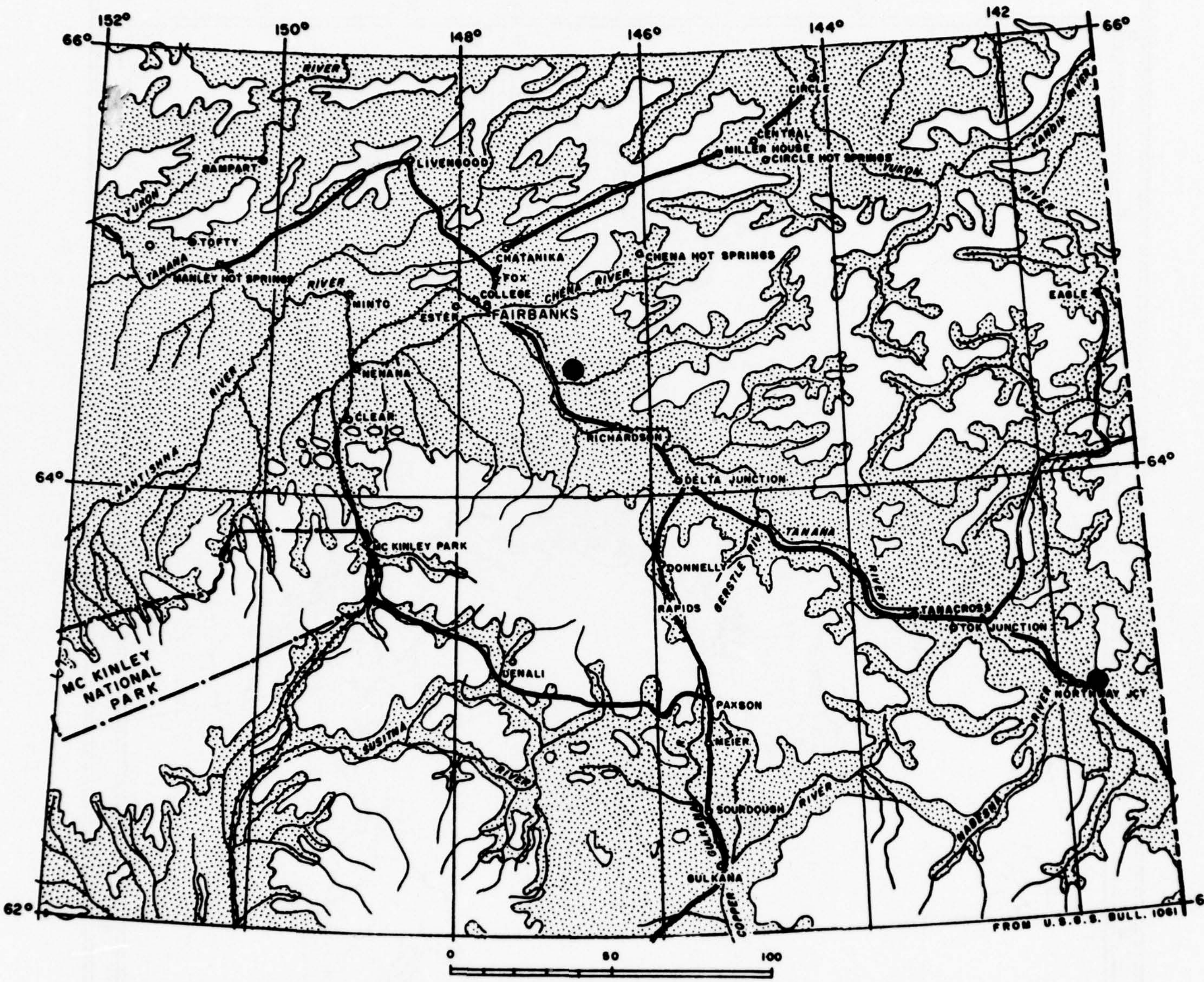
Myotis lucifugus (Maps 9, 10) - Little brown bats have been taken only rarely in the Alaskan taiga. Bats are seen quite frequently but very few specimens have been taken. I know of none collected by the common temperate zone methods of shooting and netting; all of specimens known to me have been found under shutters, shingles and other edificarian resting places. We observed bats several times in the Bonanza Creek area but were unable to collect any. Because of the almost complete absence of caves in our study region I strongly suspect the bats are migratory, but their wintering grounds are completely unknown.

Eptesicus fuscus (Maps 11, 12) - In our study region the big brown bat is known from only one specimen (in the Museum of Vertebrate Zoology, University of California) collected from behind a shutter at Shaw Creek.

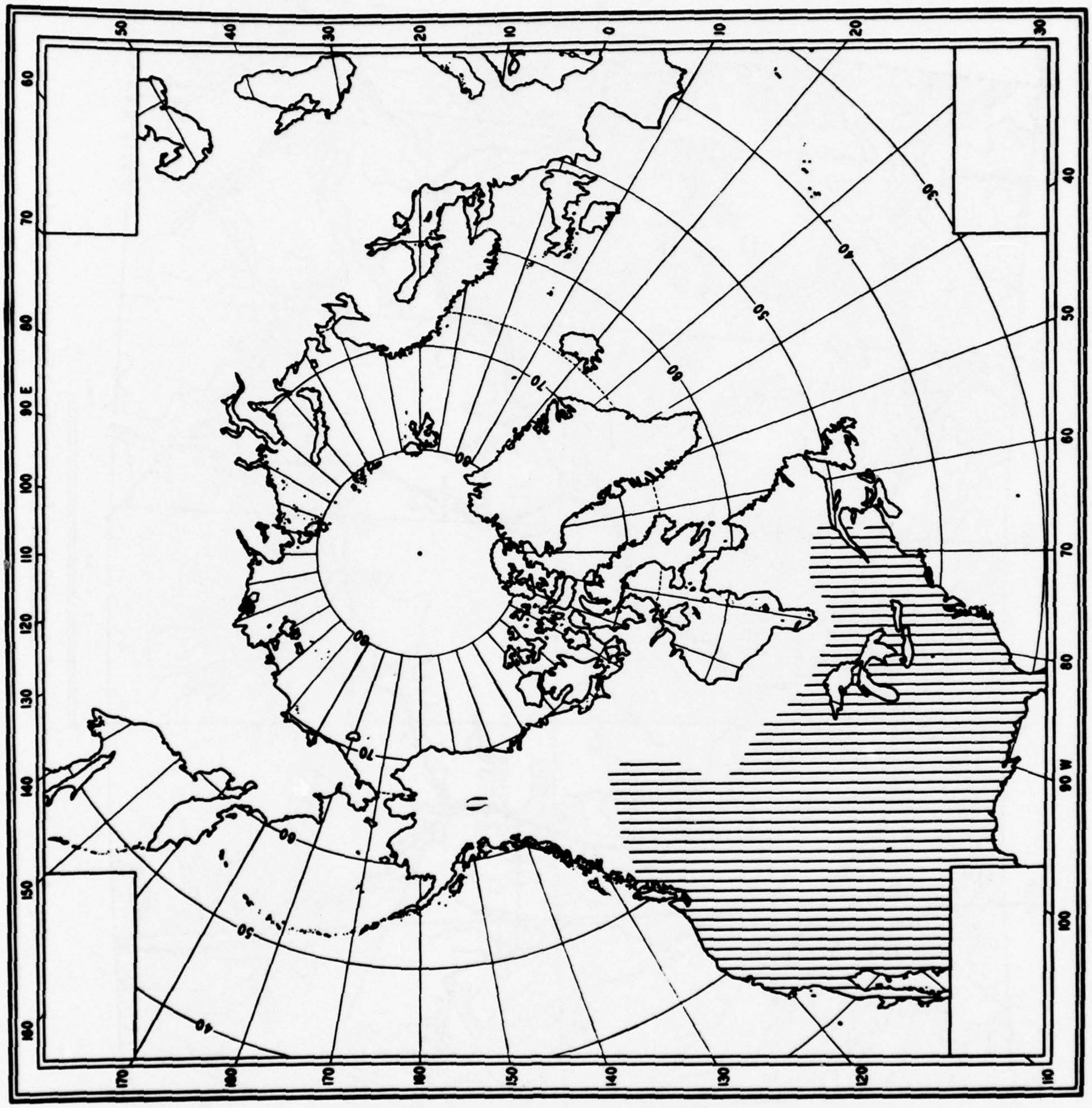
Ursus americanus (Maps 13, 14) - The black bear is a North American species and is widely distributed in our area. It is much less common in mountainous regions of Alaska than in the taiga proper. It has been postulated that direct competition between it and *Ursus horribilis* acts to exclude it from the higher country where the grizzly is more common. Black bears are nominally carnivores but ecologically they fill more the role of scavengers. They depend a great deal on vegetable food, particularly berries. In years when the berry crops fail black bears commonly intrude onto man's activities, sometimes invading camps and cabins for food.



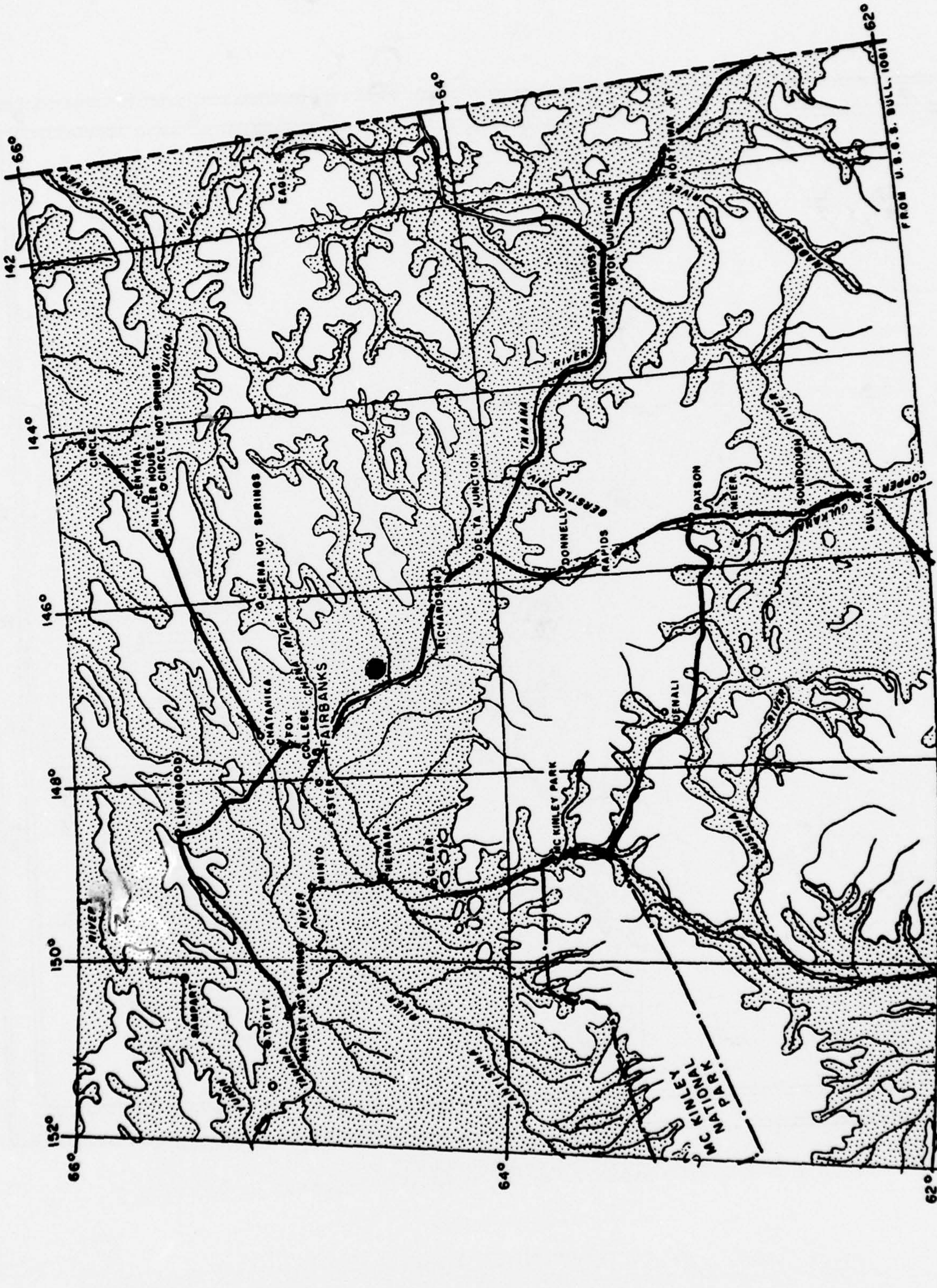
Map 9. Distribution of *Myotis lucifugus*.



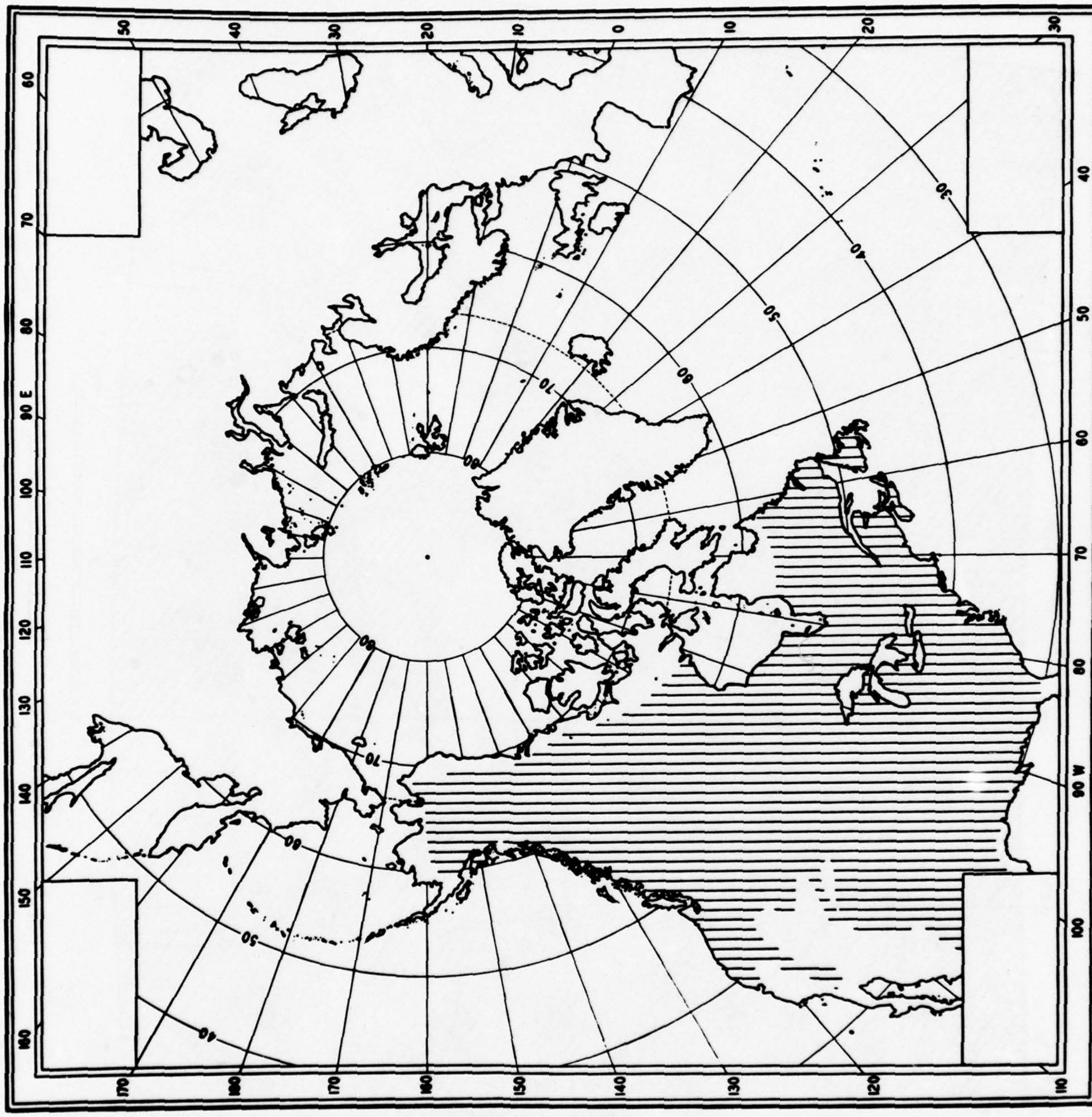
Map 10. Occurrence of Myotis lucifugus in the study region.



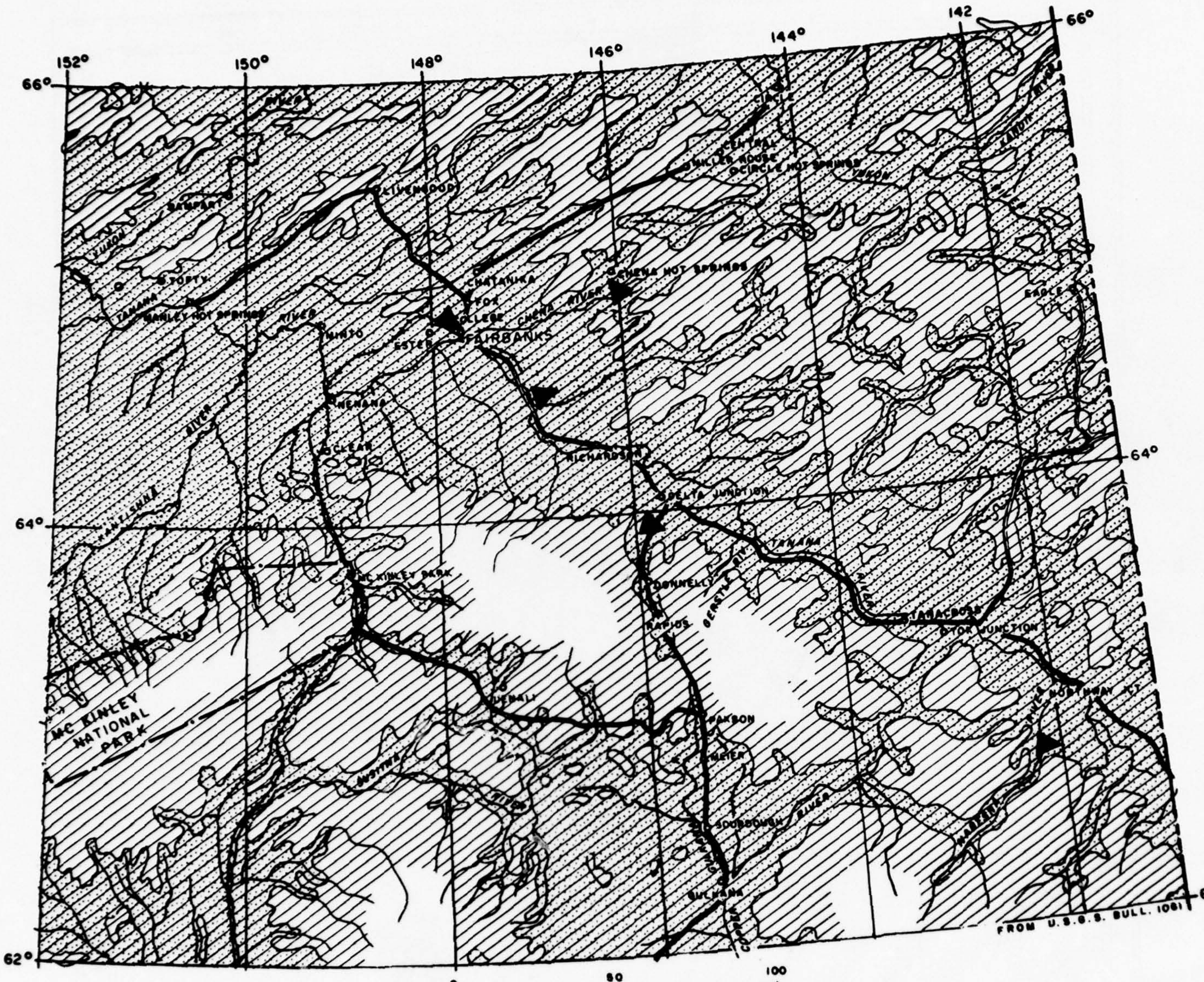
Map 11. Distribution of Eptesicus fuscus.



Map 12. Occurrence of Eptesicus fuscus in the study region.



Map 13. Distribution of <u>Ursus</u> <u>americanus</u>.



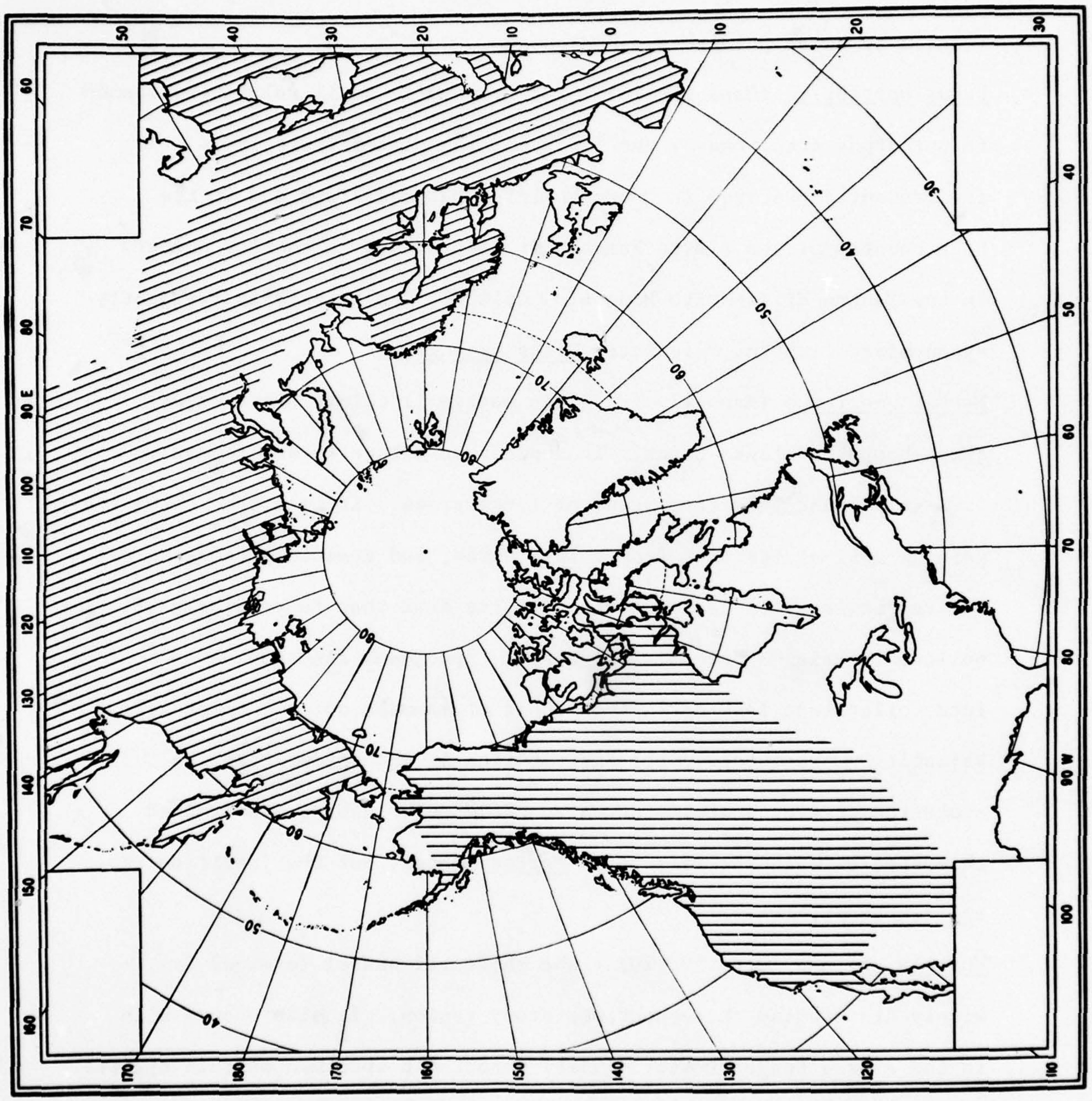
Map 14. Occurrence of Ursus americanus in the study region.

They actively scavenge in bush garbage dumps and thus may become exposed to human parasites and diseases.

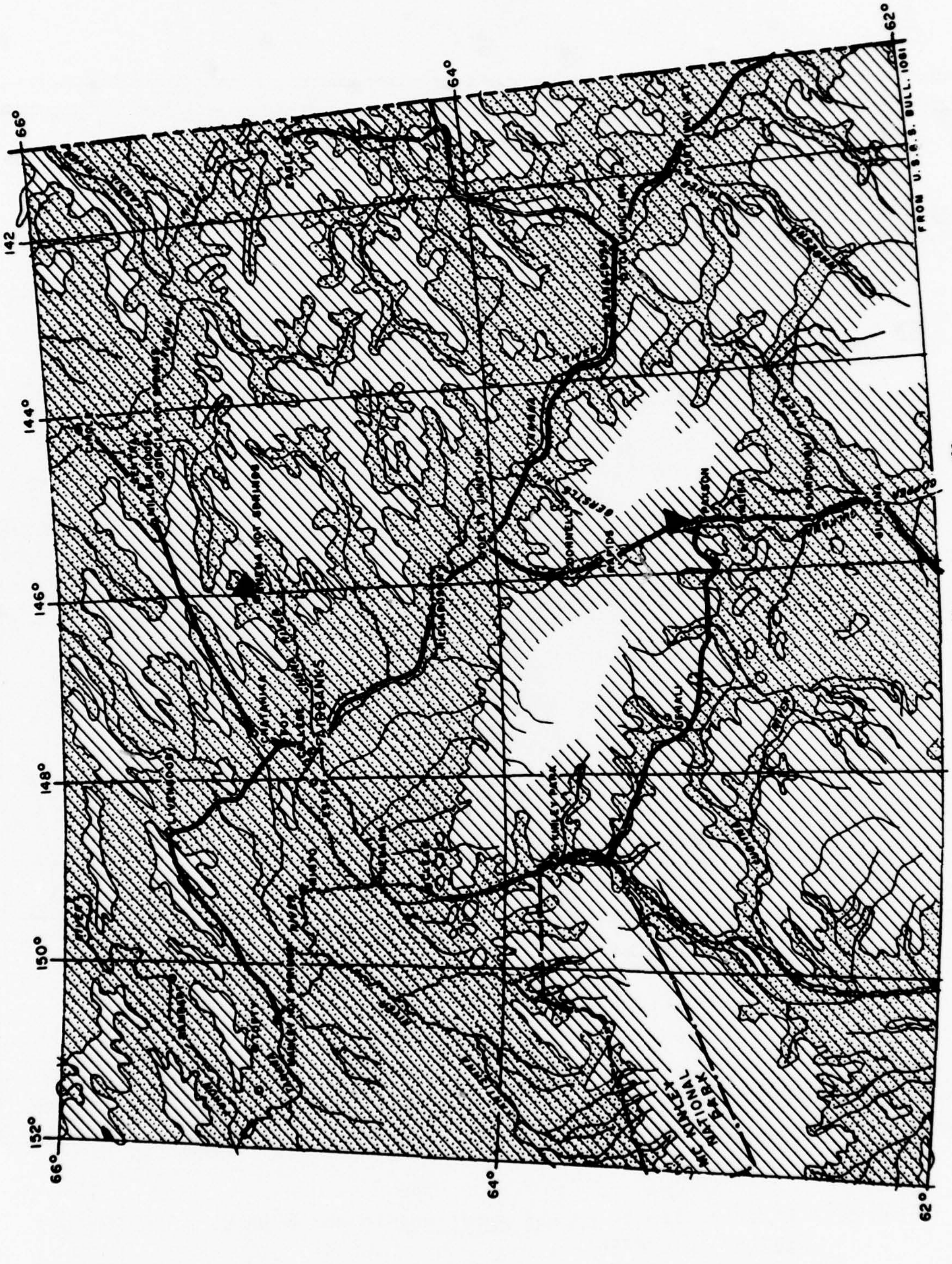
Ursus horribilis (Maps 15, 16) - The grizzly is still relatively common in our study area, one of the few remaining places where it is. It is frequently observed in Mount McKinley National Park and in the high country of the Alaska Range. It also occurs in smaller numbers in the Tanana Hills-White Mountains upland. The grizzly is frequently synonymized with the Palearctic Ursus arctos.

Martes americana (Maps 17, 18) - The marten is thinly distributed throughout the Alaska taiga. It depends on mature spruce forest and is rarely found away from areas of large trees. It is a true carnivore, gaining most of its diet from voles, hares, and sometimes red squirrels. The red squirrel is less important in its diet than is popularly believed. Being a valuable fur-bearer, specimens find their way into collections less often than those of mammals not so commercially valuable. Consequently, its distribution is much wider than the scattered specimens would indicate. Some authors have synonymized this species with the Palearctic Martes martes, but the justification appears scant.

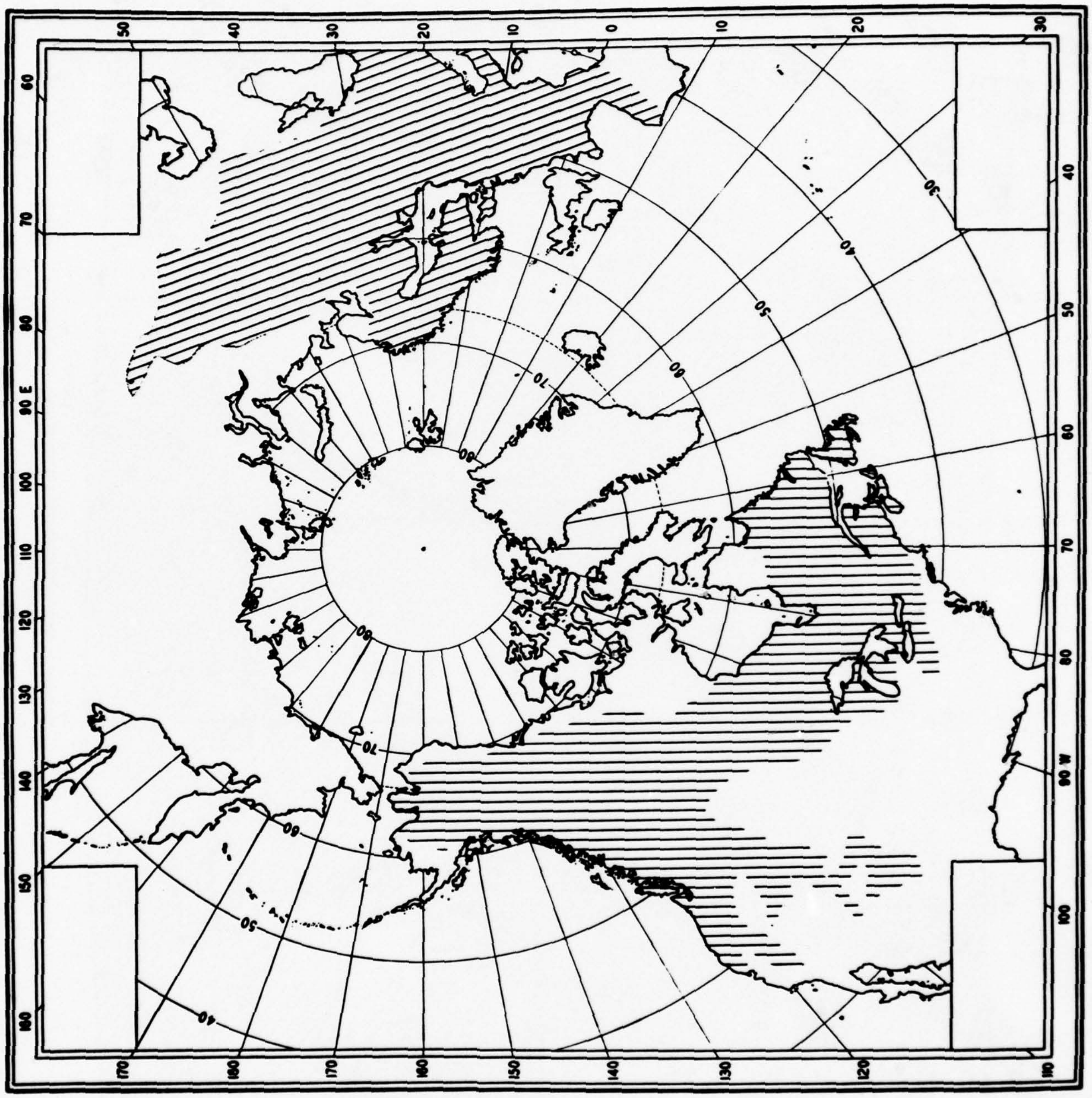
Mustela erminea (Maps 19, 20) - The shorttail weasel (ermine) is widely distributed throughout our study region. It also occurs high in the Alaska Range; Pruitt (1957b) reported a specimen of this species found mummified at the 15,000 foot level on Mount McKinley, some 12,000 feet above timberline. Its presence and numbers depends directly on the available biomass of prey. Consequently, when voles and hares are



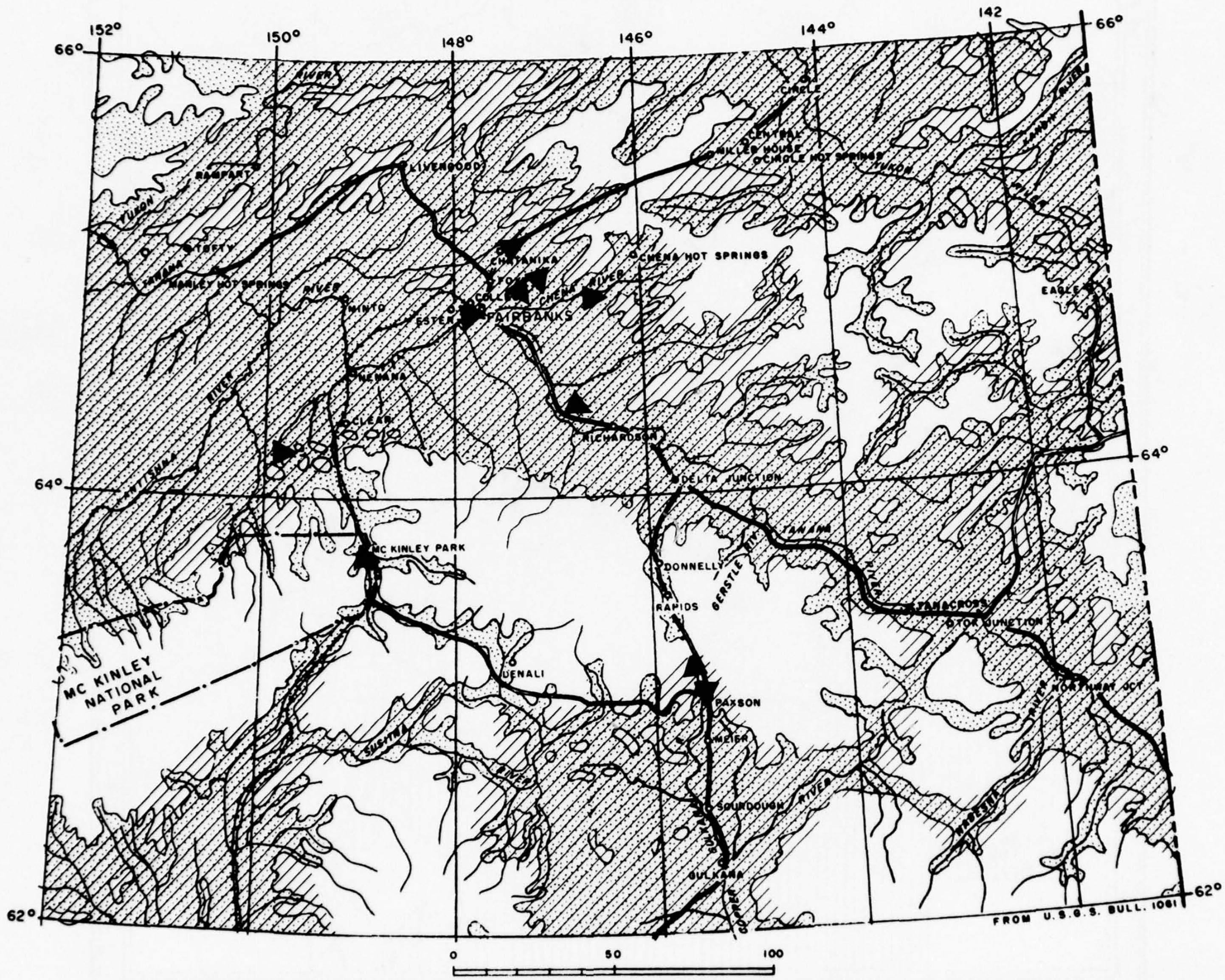
Map 15. Distribution of Ursus horribilis in North America and Ursus arctos in Eurasia.



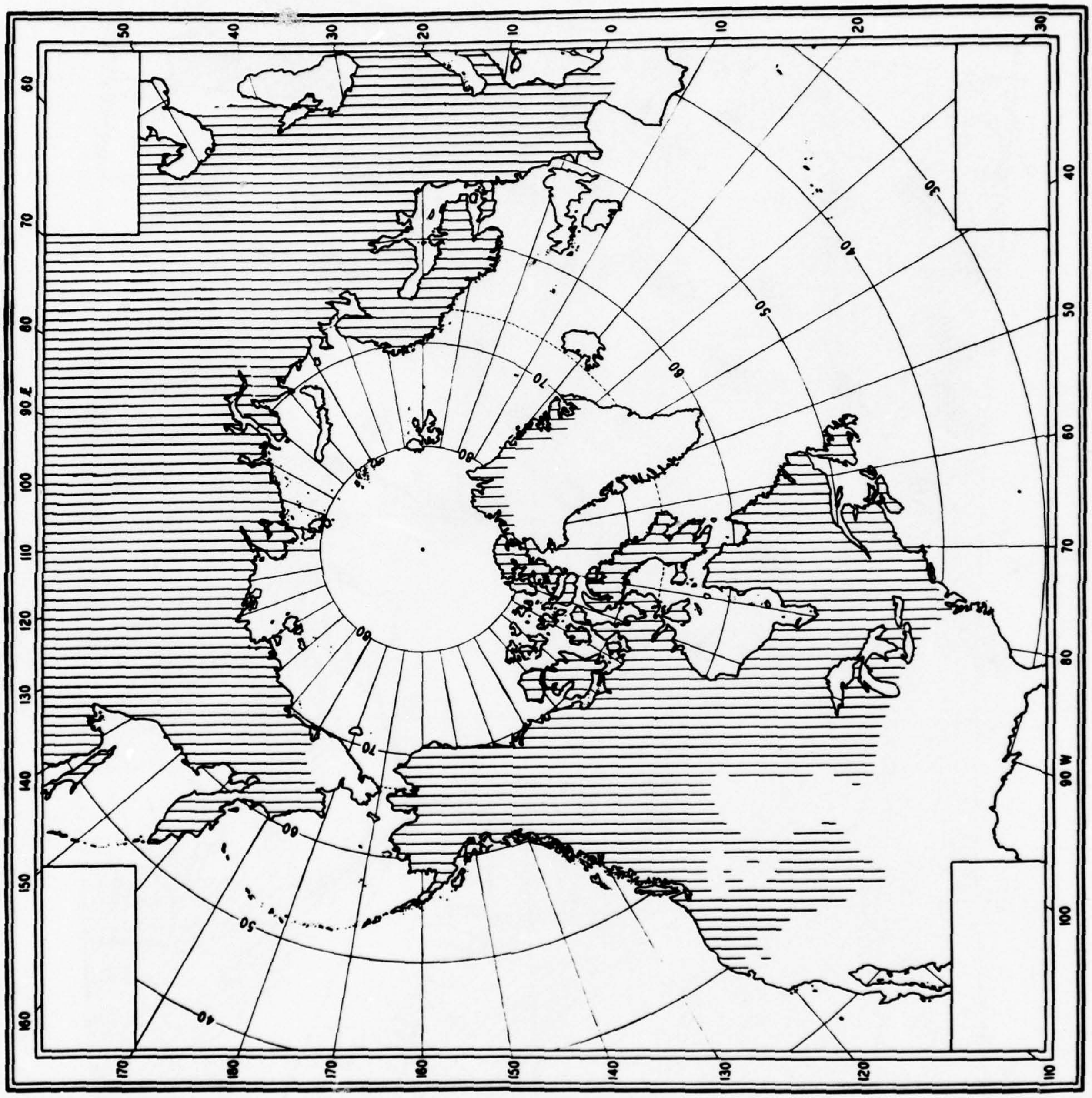
Map 16. Occurrence of <u>Ursus horribilis</u> in the study region.



Map 17. Distribution of Martes americana in North America and Martes martes in Eurasia.



Map 18. Occurrence of *Martes americana* in the study region.



Map 19. Distribution of *Mustela erminea*.

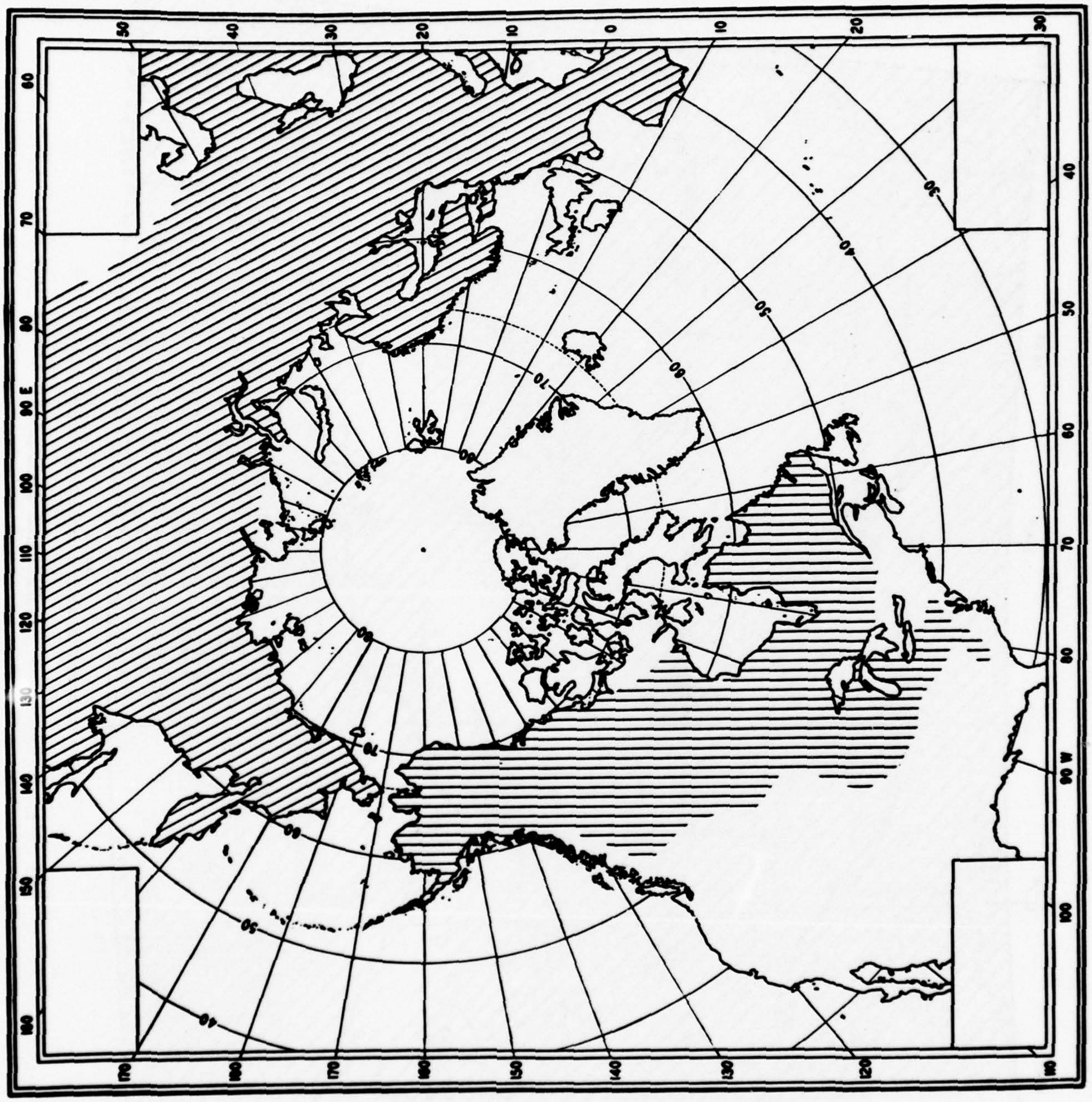
Map 20. Occurrence of Mustela erminea in the study region.

at low ebb, weasels are rare, but when voles and hares are high, weasels may become very common. This species is a carnivore and as such is at the peak of the taiga food web. It is Holarctic in distribution.

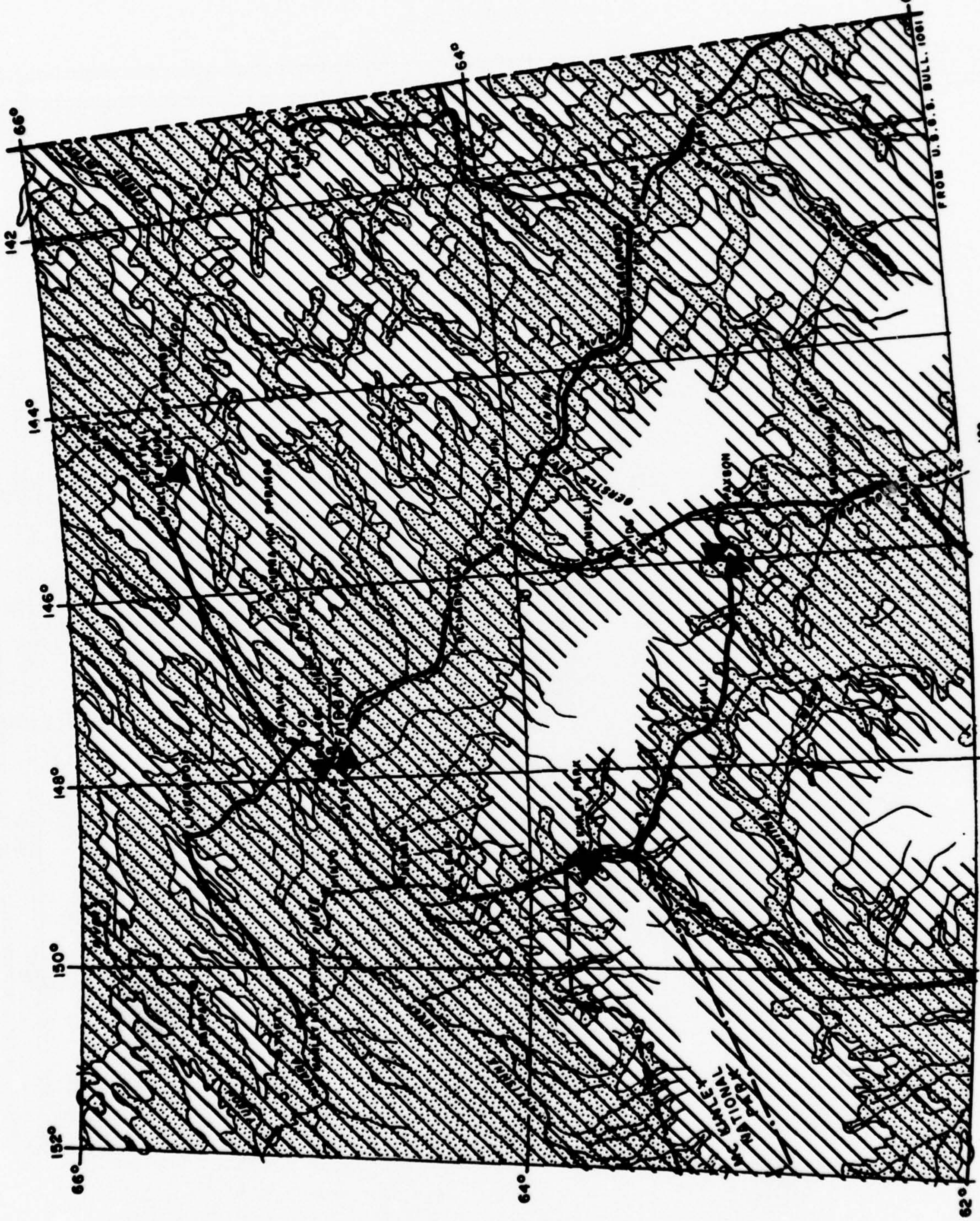
Mustela rixosa (Maps 21, 22) - The least weasel is the world's smallest representative of the Order Carnivora. It is widely distributed but rarely taken. It is a true carnivore in the taiga food web but it, in turn, may occasionally fall prey to large raptorial birds. This species is closely dependent on the state of the vole populations, much more so than the larger preceding species. Some authors (Hall, 1951) have lumped this species with the Palearctic Mustela nivalis complex, with justification. Hall, however, pointed out the taxonomic thicket encountered here, and we follow his usage of M. rixosa for both Old and New World forms.

Mustela vison (Maps 23, 24) - The mink is another valuable furbearer and is widely distributed in our study region. It is semi-aquatic in habits and is consequently closely associated with water courses and ponds. It feeds on whatever is available -- mussels, small fish, voles, muskrats, birds. Its close association with muskrats indicates an equally close susceptibility to zoonoses that may affect muskrats.

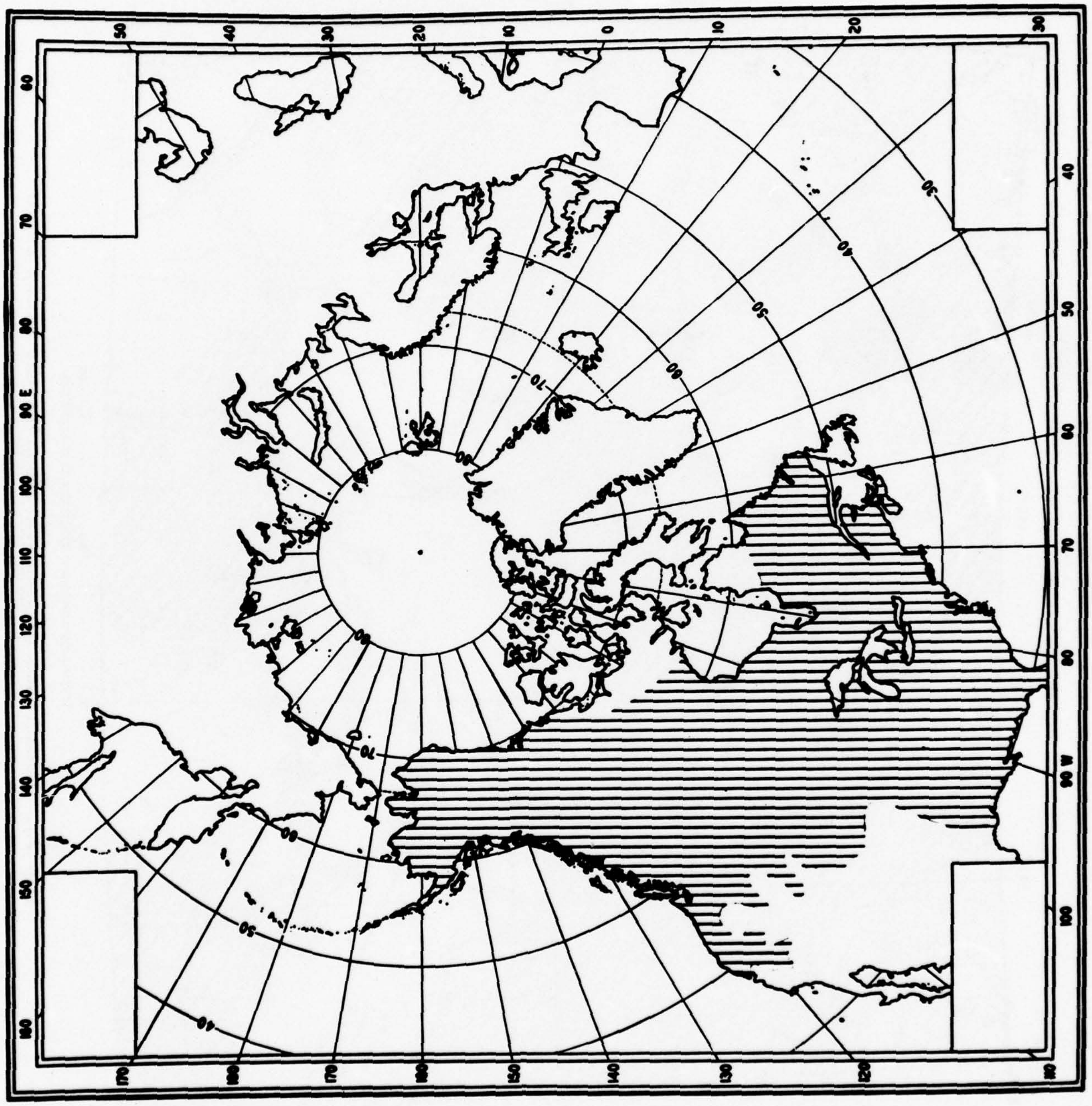
Gulo luscus (Maps 25, 26) - The wolverine is sparsely distributed throughout the study region, but is relatively more common in the high country of the Alaska Range. Indeed, the one animal that is usually reported by high-altitude mountain climbing parties in this



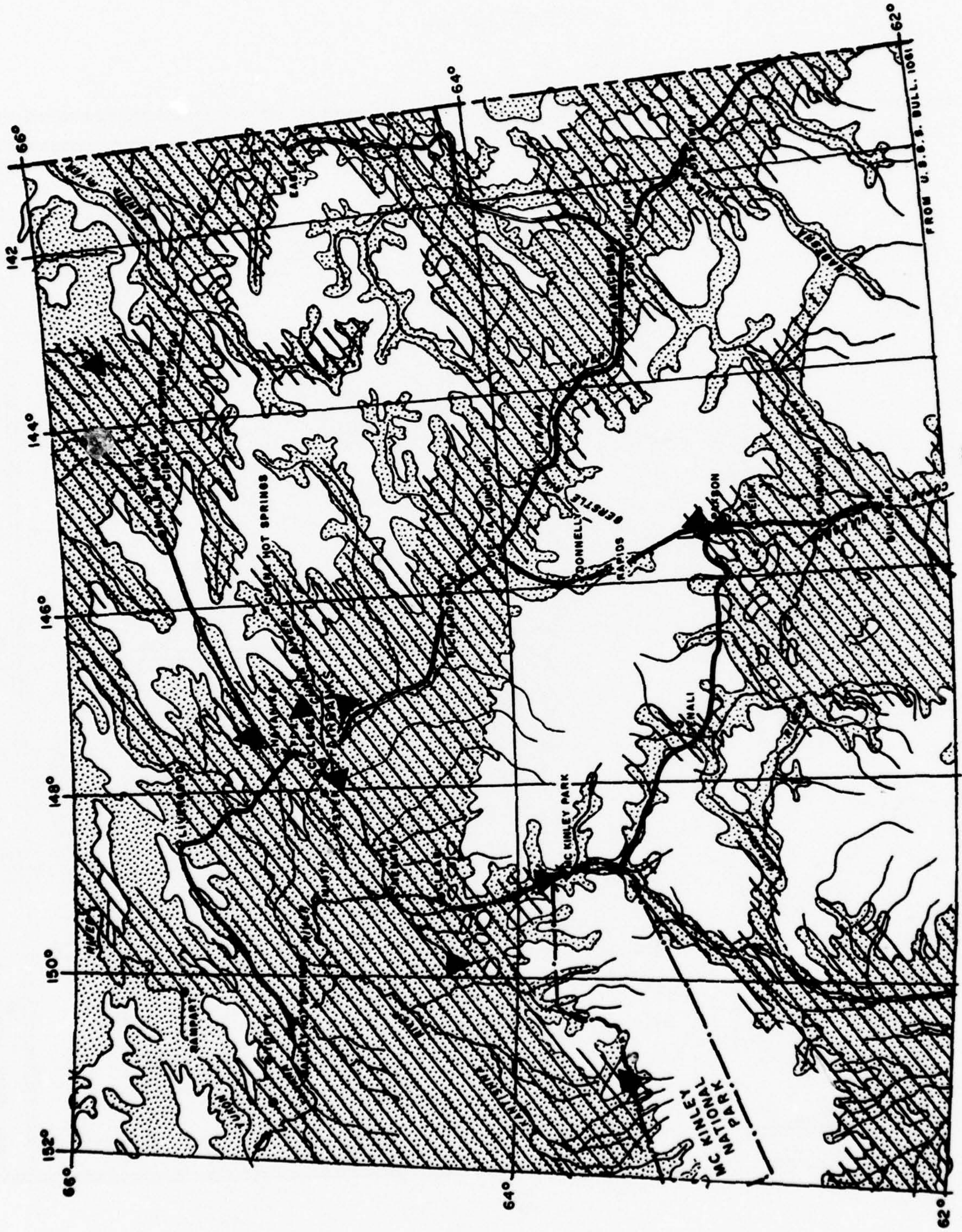
Map 21. Distribution of Mustela rixosa in North America and Eurasia.



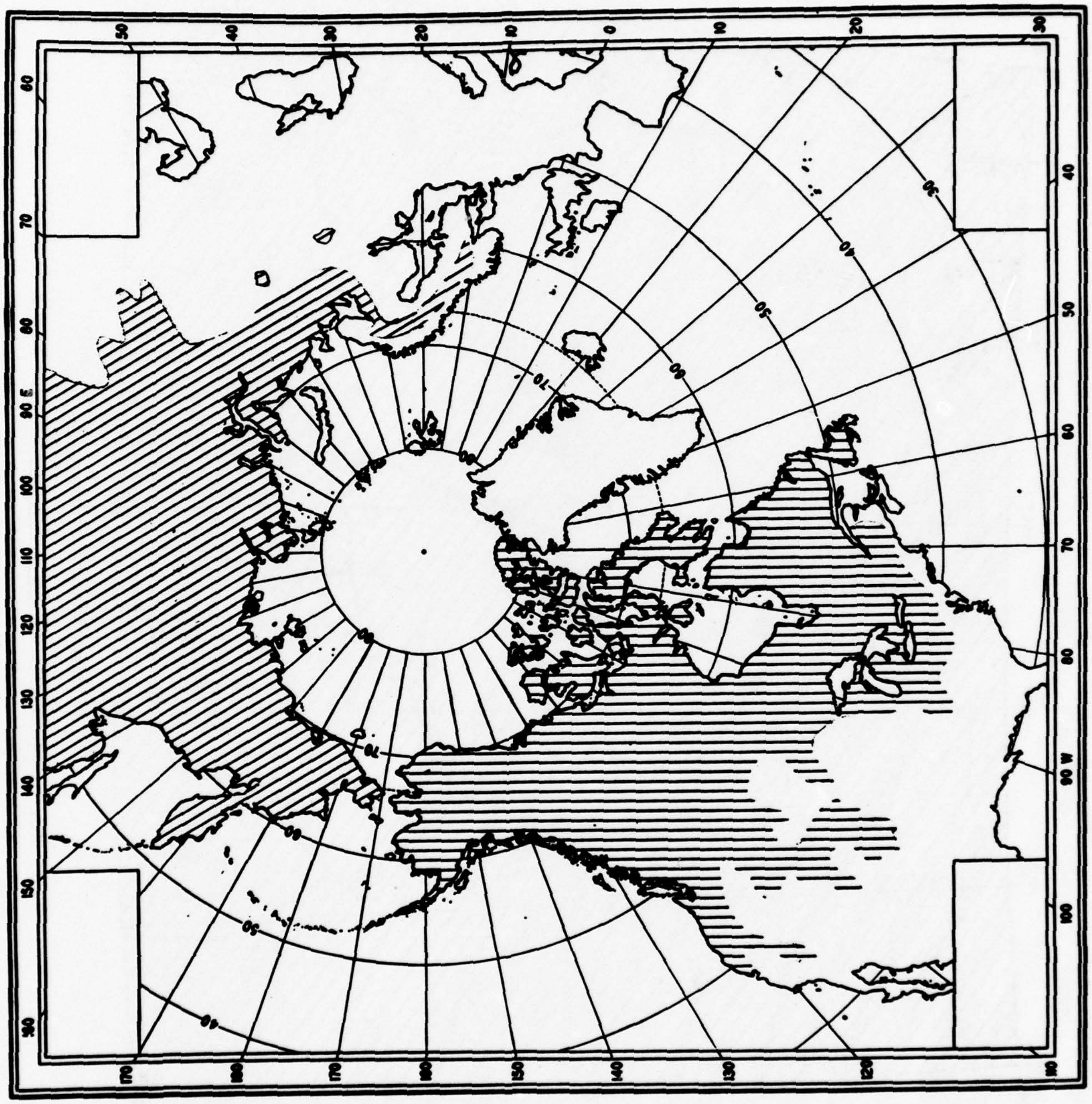
Map 22. Occurrence of *Mustela rixosa* in the study region.



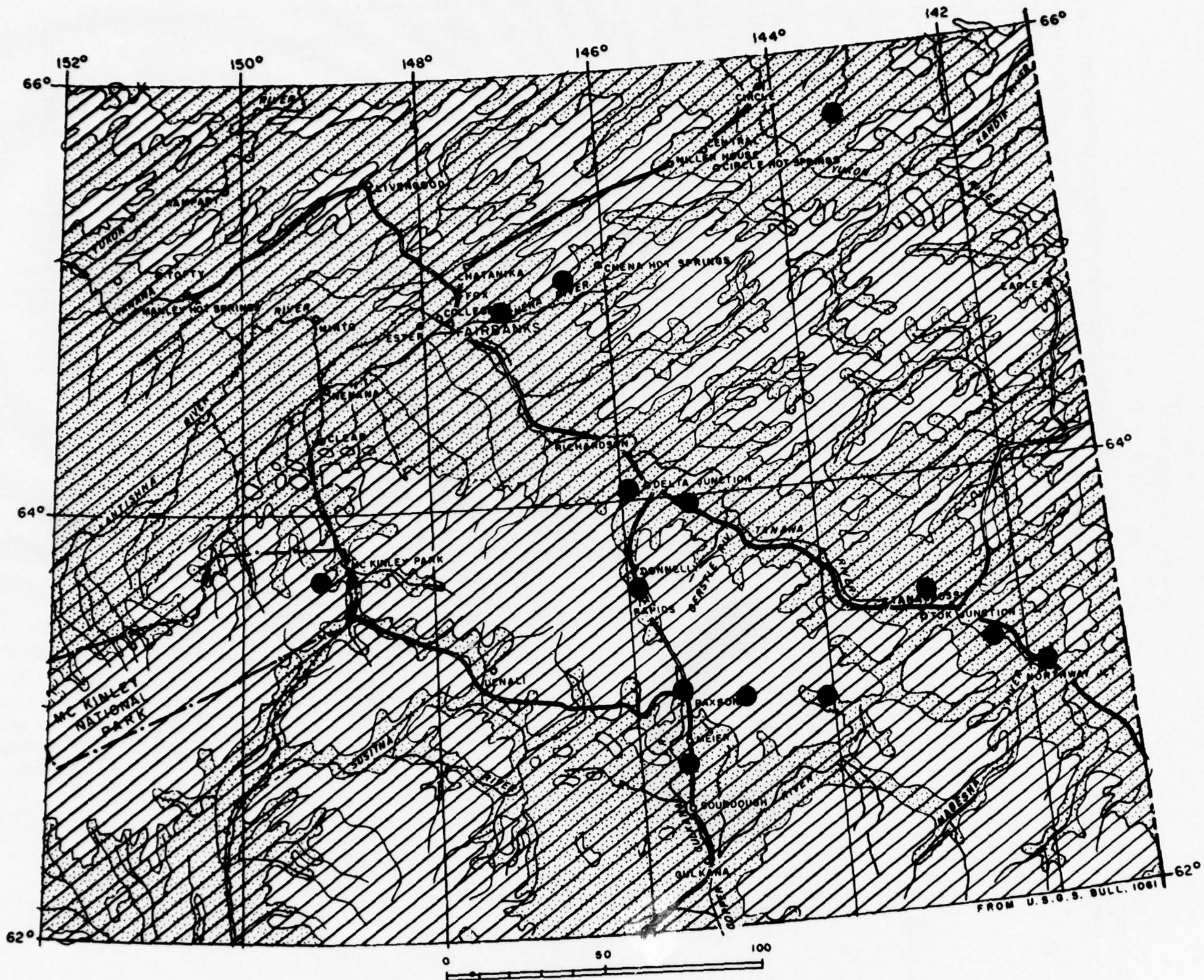
Map 23. Distribution of *Mustela vison*.



Map 24. Occurrence of Mustela vison in the study region



Map 25. Distribution of Gulo luscus in North America and Gulo gulo in Eurasia.

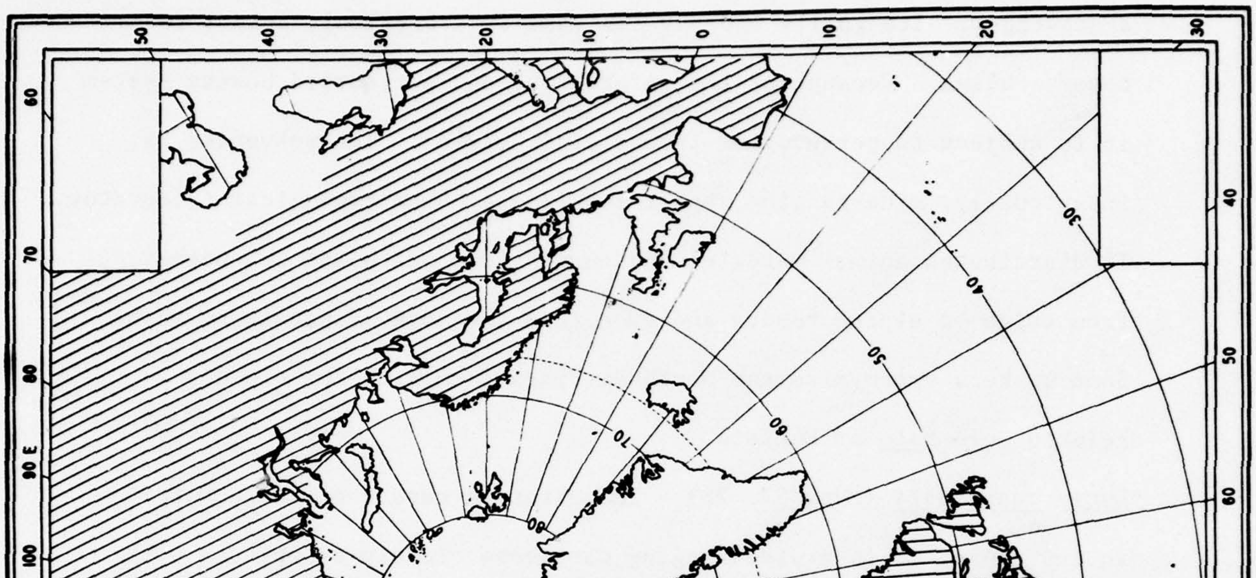


Map 26. Occurrence of Gulo luscus in the study region.

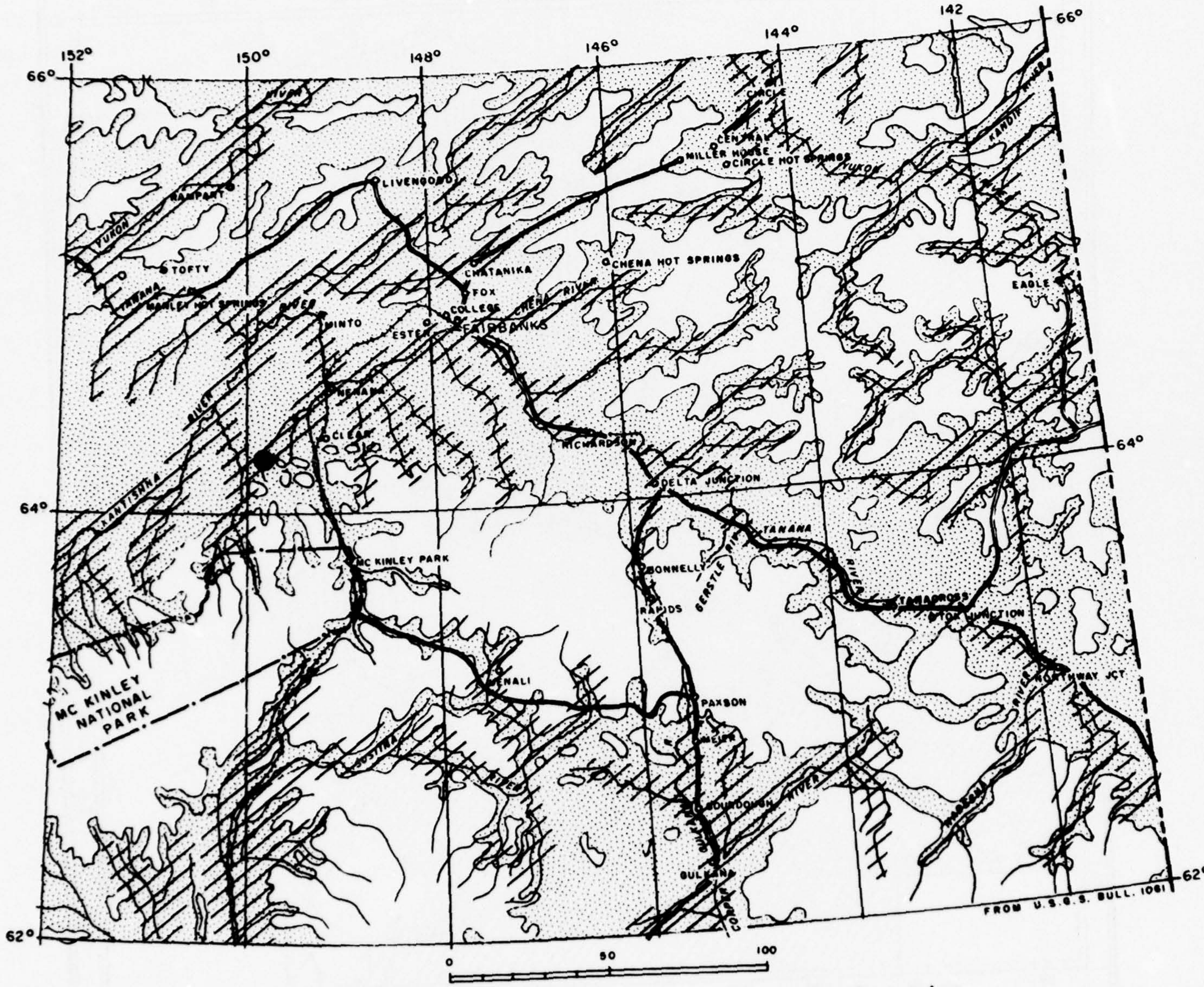
region is the wolverine. It is a nominal carnivore but ecologically a scavenger. Its rarity and shyness make it a difficult animal to observe alive. Because of the unfortunate and antiquated bounty system it is subject to persecution in our study region. The wolverine is, individually, wide-ranging, and I look on it as an ecological integrator. It distributes animal material and energy from one place to another, from taiga to alpine tundra and even into the zone of permanent snow. Some workers synonymize the North American form with the closely related Gulo gulo of Eurasia.

Lutra canadensis (Maps 27, 28) - The otter is rarely common anywhere in its range; it is a wide-ranging carnivore closely associated with water. It is primarily a fish-eater but will also take small mammals and birds if opportunity offers. Being a valuable fur-bearer, specimens do not often find their way into scientific collections. I have observed individuals and tracks in the upper Gulkana drainage near Paxson Lake. Some authors have lumped this species with the Old World Lutra lutra, but again, justification appears scant.

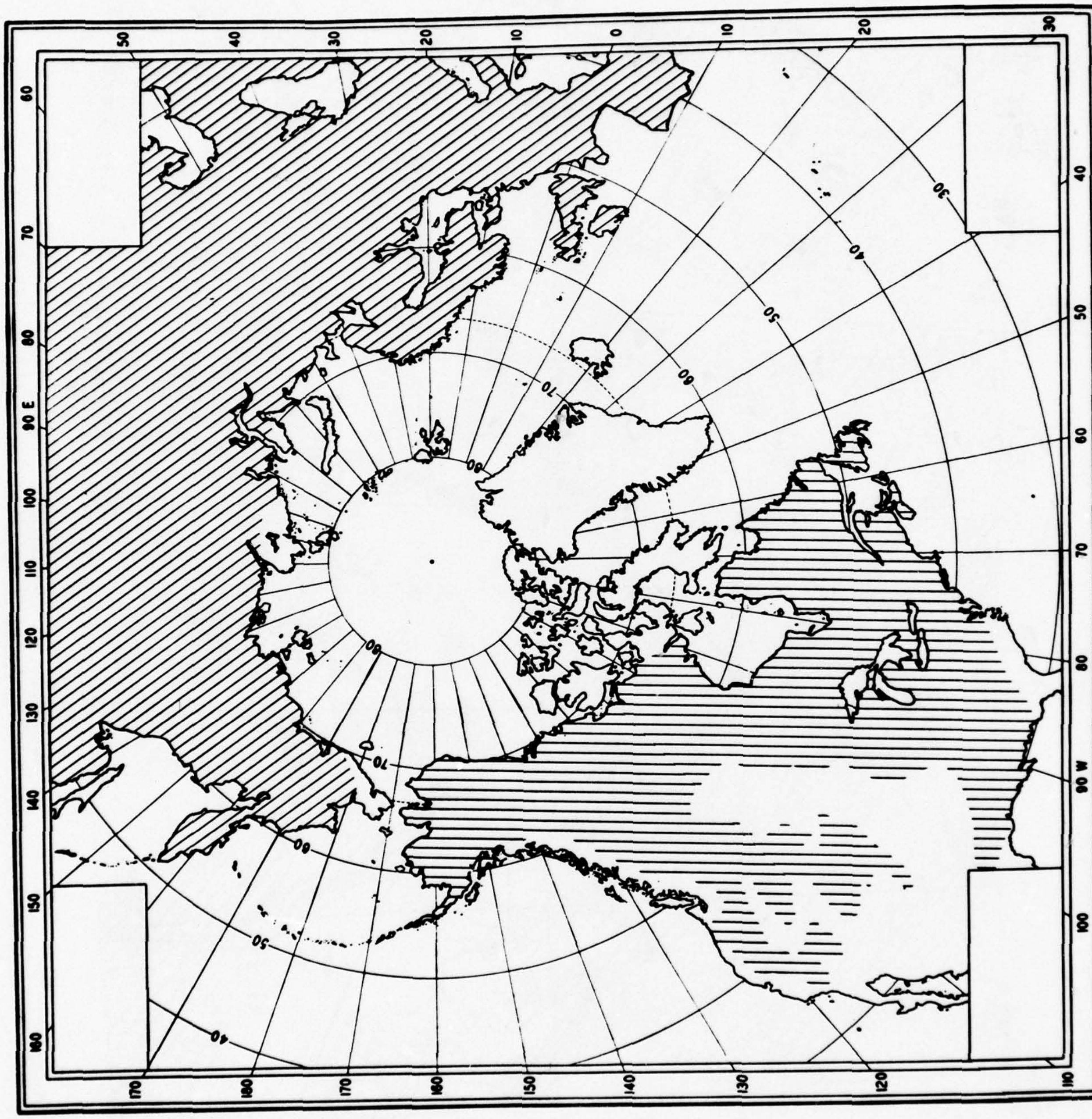
Vulpes fulva (Map 29, 30) - The colored fox is one of the common carnivores of our study region. It has been observed or taken in virtually all habitats, although it seems more common in disturbed areas. Foxes are true scavengers and will feed on anything even remotely edible -- voles, hares, ground squirrels, fish, carrion, berries, garbage. Nonetheless, there appears a direct relationship between its numbers and the general state of the small mammals in any local area. The exact taxonomic position of the colored fox is cloudy.



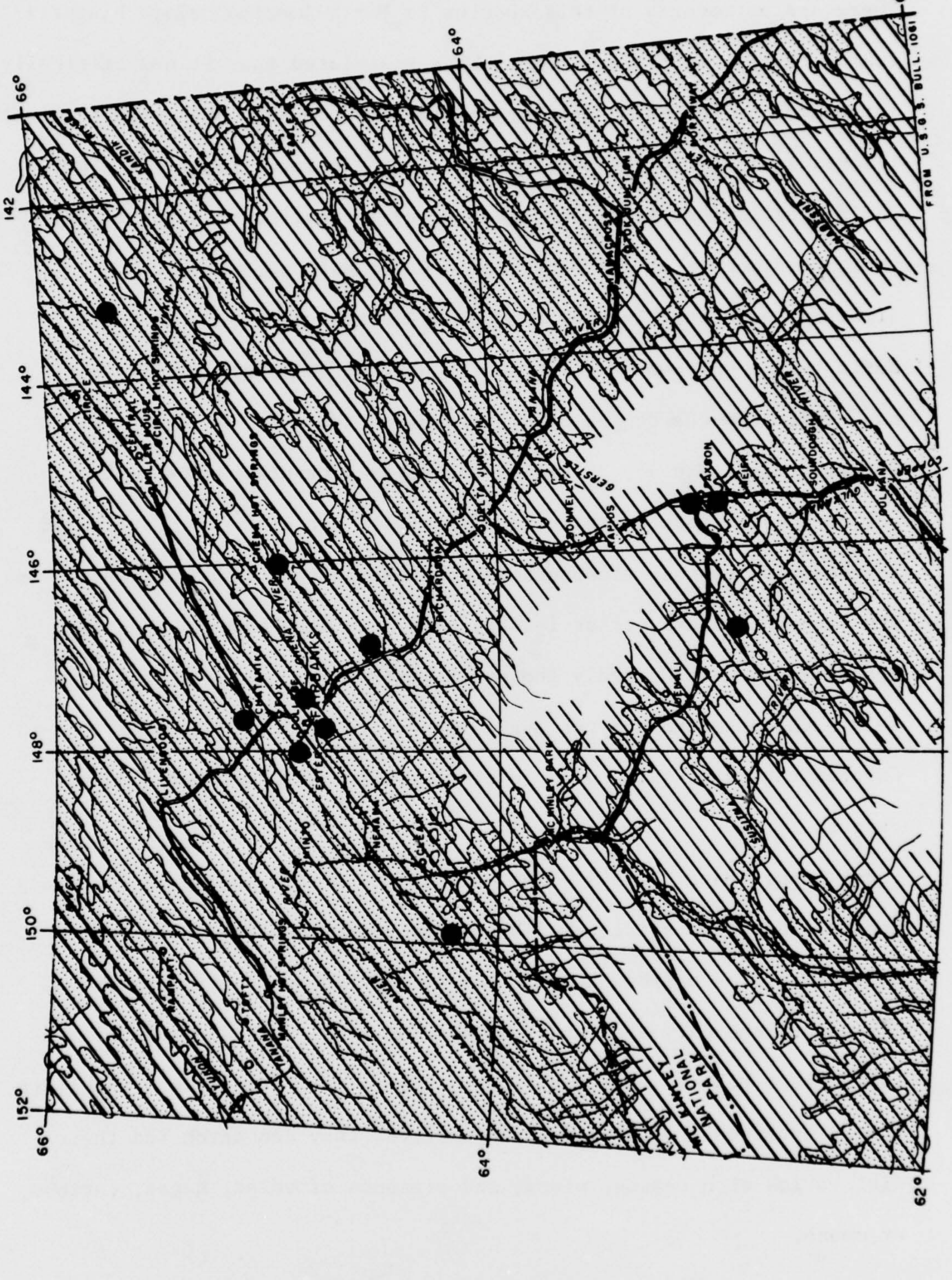
Map 27. Distribution of Lutra canadensis in North American and Lutra lutra in Eurasia.



Map 28. Occurrence of Lutra canadensis in the study region.



Map 29. Distribution of Vulpes fulva in North America and Vulpes vulpes in Eurasia.

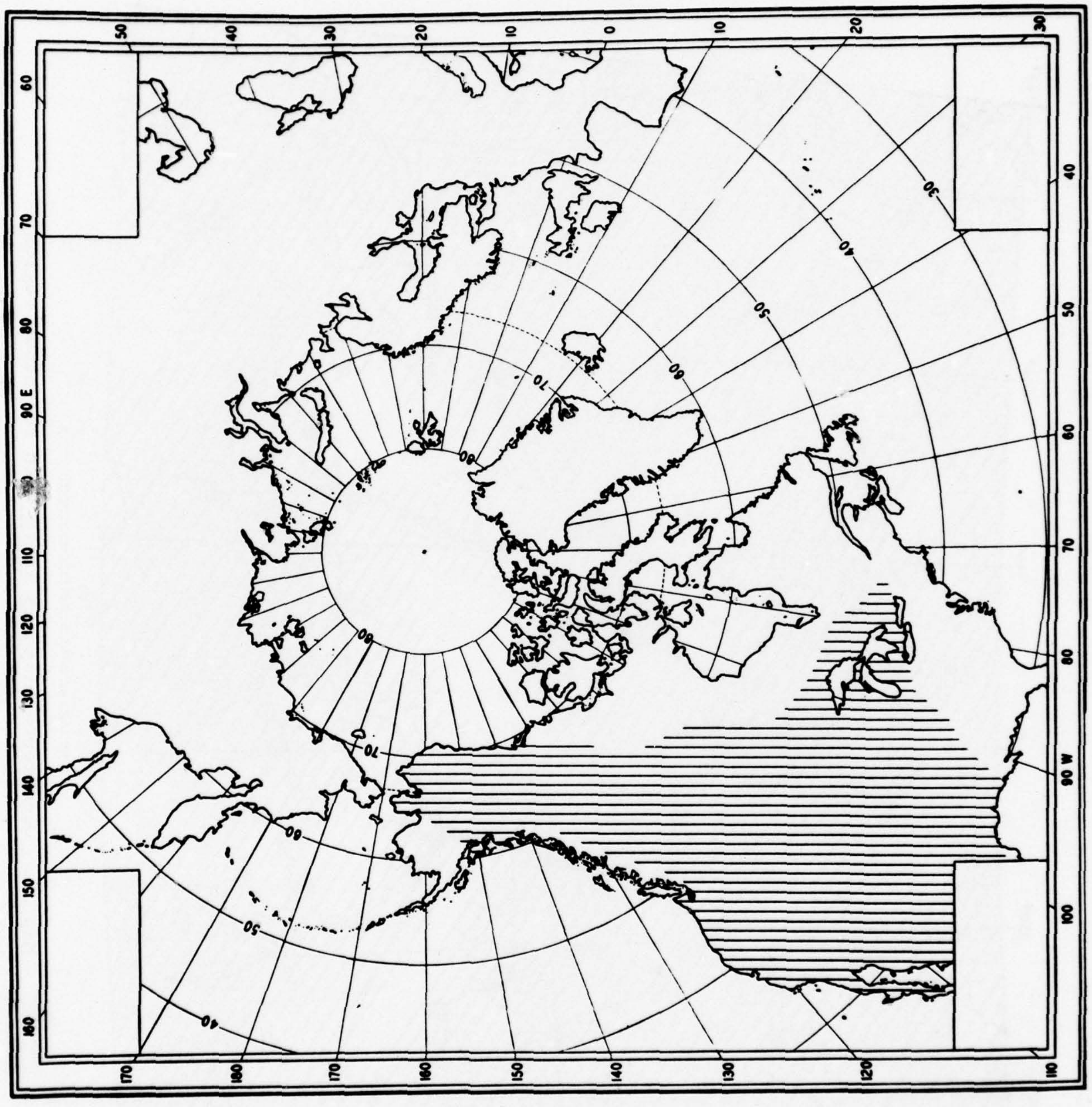


Map 30. Occurrence of Vulpes fulva in the study region.

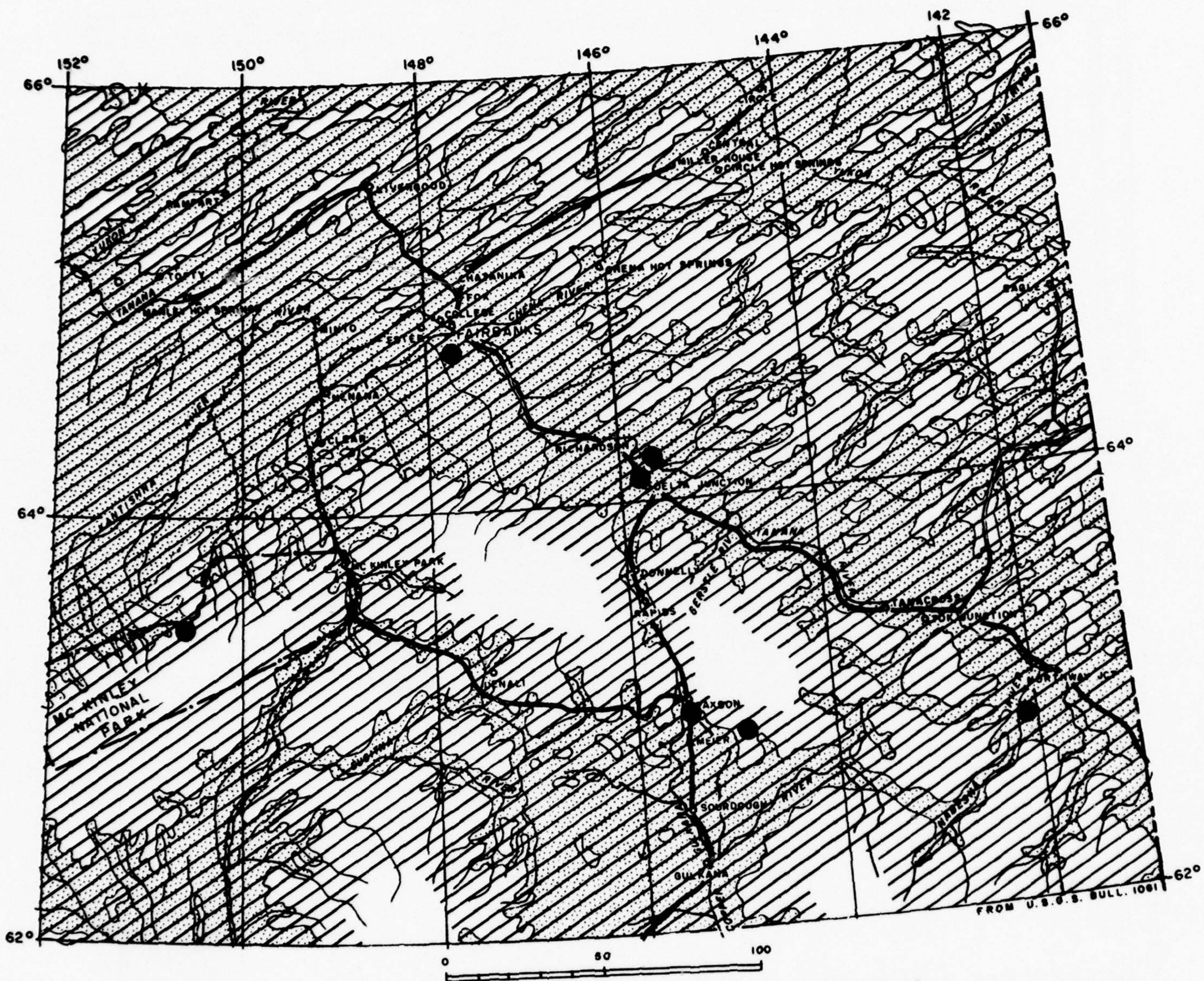
There are no records of this species in North America before historic times; consequently some authors have postulated that it was originally introduced by the early settlers on the east coast. This appears highly illogical since, in the North at least, the colored fox fills a well-defined ecological niche and gives every indication of being a well-integrated member of the ecosystem. Other authors, with scant justification, advocated lumping the North American species with the Old World _Vulpes vulpes_. We continue to use the name _Vulpes fulva_ but have indicated the ranges of both forms on the map.

Canis latrans (Map 31, 32) - The coyote is a carnivore that will actually eat almost anything, and is widely but sparsely distributed in the study region. Indications are that the coyote has extended its range northward, or at least become much more common, in rather recent years. Undoubtedly the great extirpation of the wolf has left a vacant niche and the adaptable coyote has moved into it. Coyotes can exist quite well in close proximity to man but wolves cannot.

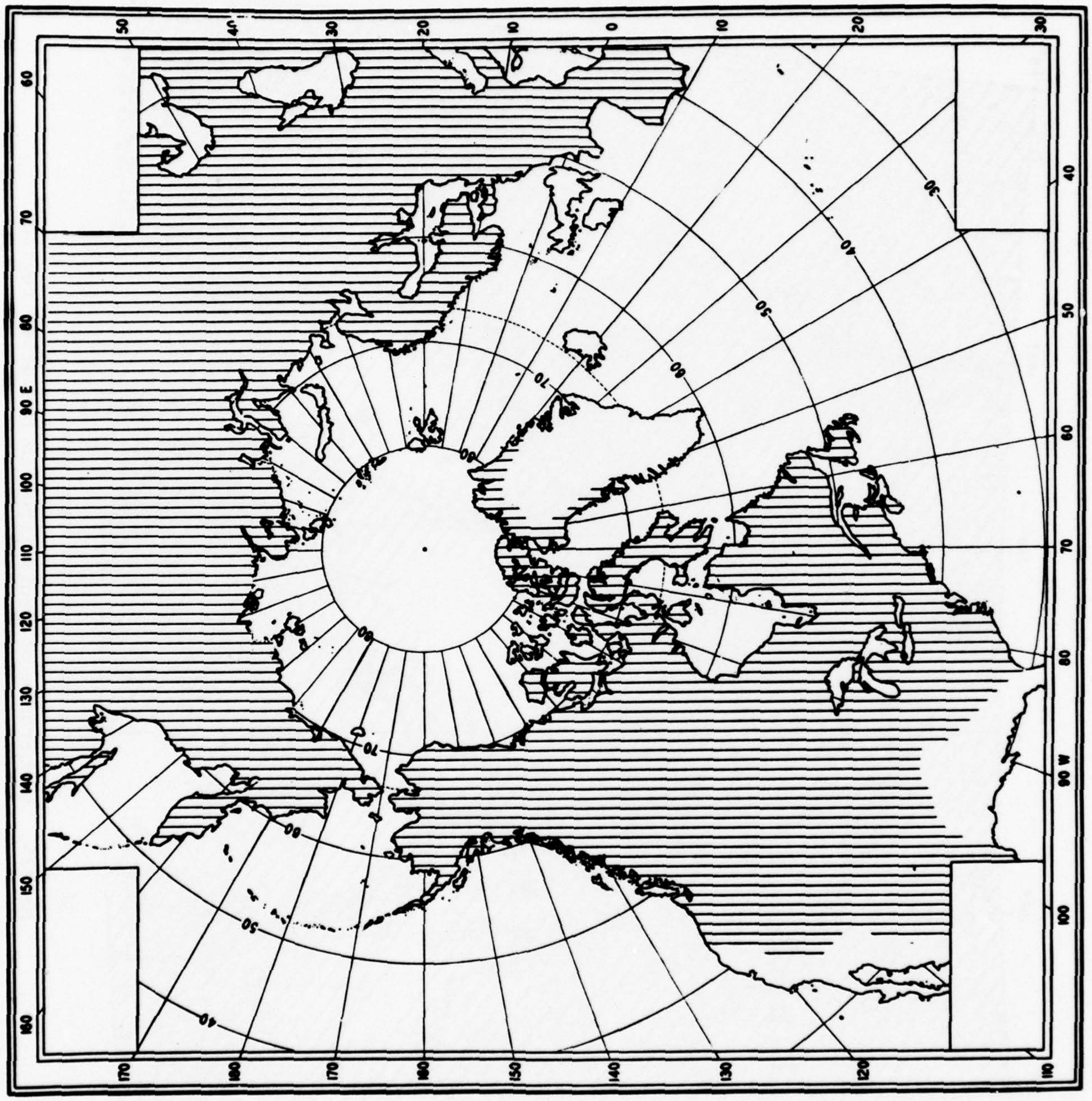
Canis lupus (Maps 33, 34) - The wolf is now a rare animal in our study region. Some are still taken by aerial bounty hunters. The region of the Nelchina caribou herd is now a relative sanctuary for wolves, but almost the only area where wolves may still be found regularly is in Mount McKinley National Park. The wolf is primarily a carnivore, but an opportunist. They feed on whatever they can catch and their diet varies with season, place, and presence of voles, hares, caribou, or moose.



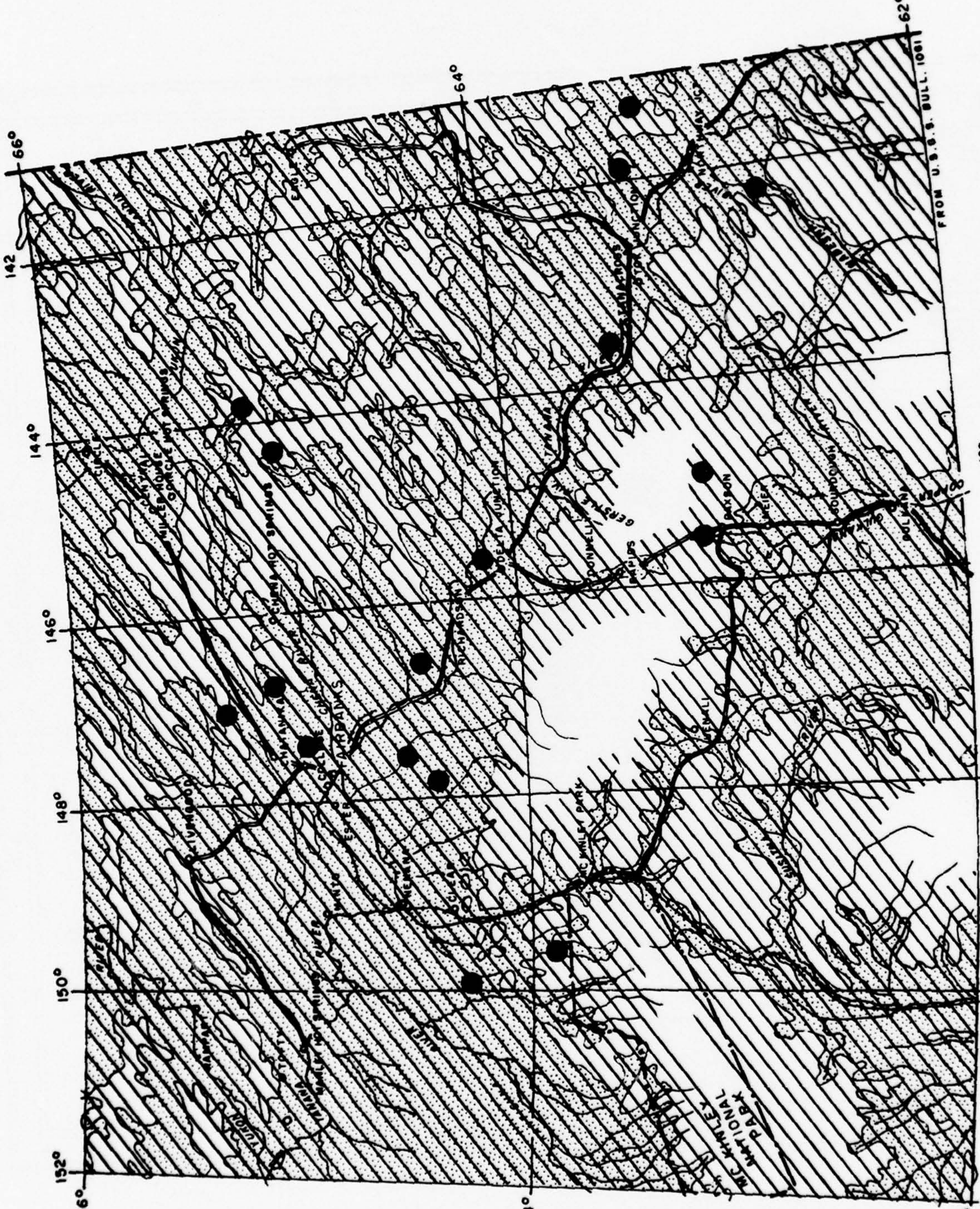
Map 31. Distribution of <u>Canis</u> <u>latrans</u>.



Map 32. Occurrence of Canis latrans in the study region.



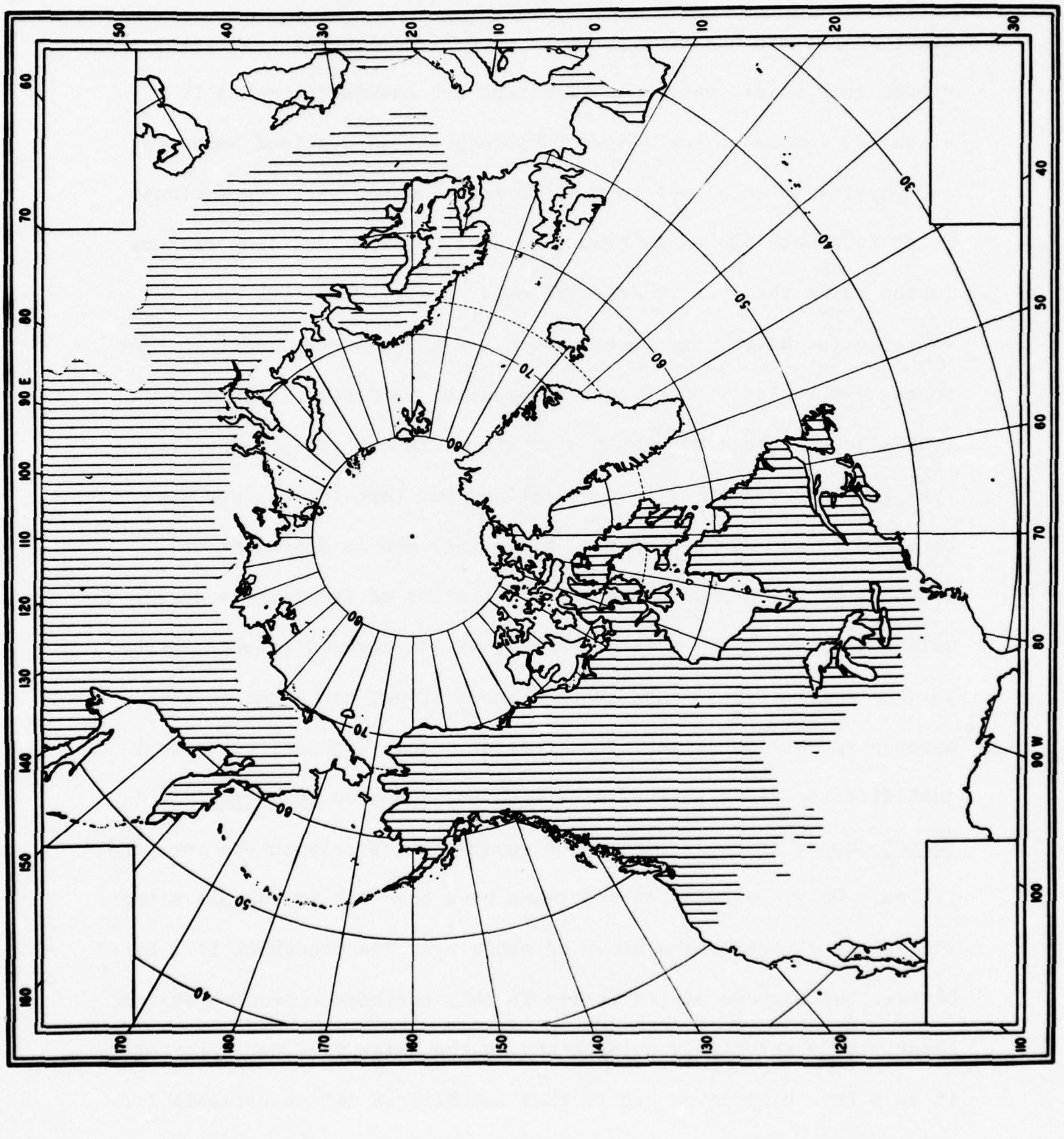
Map 33. Distribution of Canis lupus.



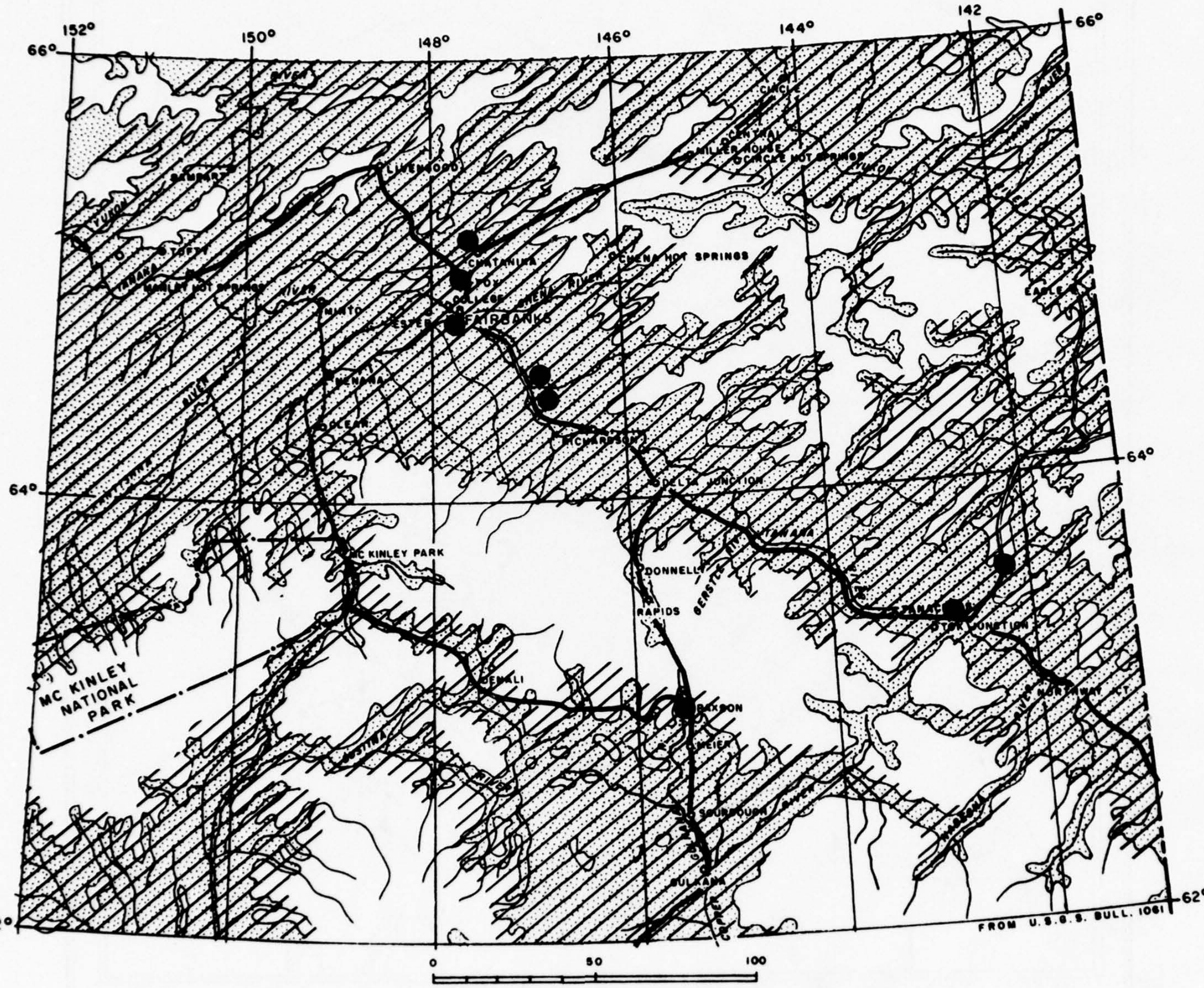
Map 34. Occurrence of Canis lupus in the study region.

Lynx canadensis (Maps 35, 36) - The lynx is also a carnivore in the taiga food web. It is highly specialized for taiga conditions -- light weight and huge feet give it good flotation for traversing the winter snow cover; extremely efficient fur insulation makes it virtually immune to low winter temperatures; specialized behavior and physiology enable it to utilize the snowshoe hare populations which fluctuate violently over the years. During non-snow seasons in the taiga the lynx is detected only rarely. The lynx is a valuable fur-bearer and some numbers are trapped each season. Lynx appear particularly prone to ectoparasites, and some individual lynxes support huge populations of them. In our study region, the lynx is found primarily below treeline, but individuals have been observed in the alpine tundra. Since they are so dependent on snowshoe hares they are more common in areas of secondary succession -- willow thickets along stream courses, willow-covered islands in the large glacial streams such as the Tanana River, old burns in the aspen-birch-willow stages of succession. Some authors, with scant justification, lump this species with the Eurasian *Lynx lynx*.

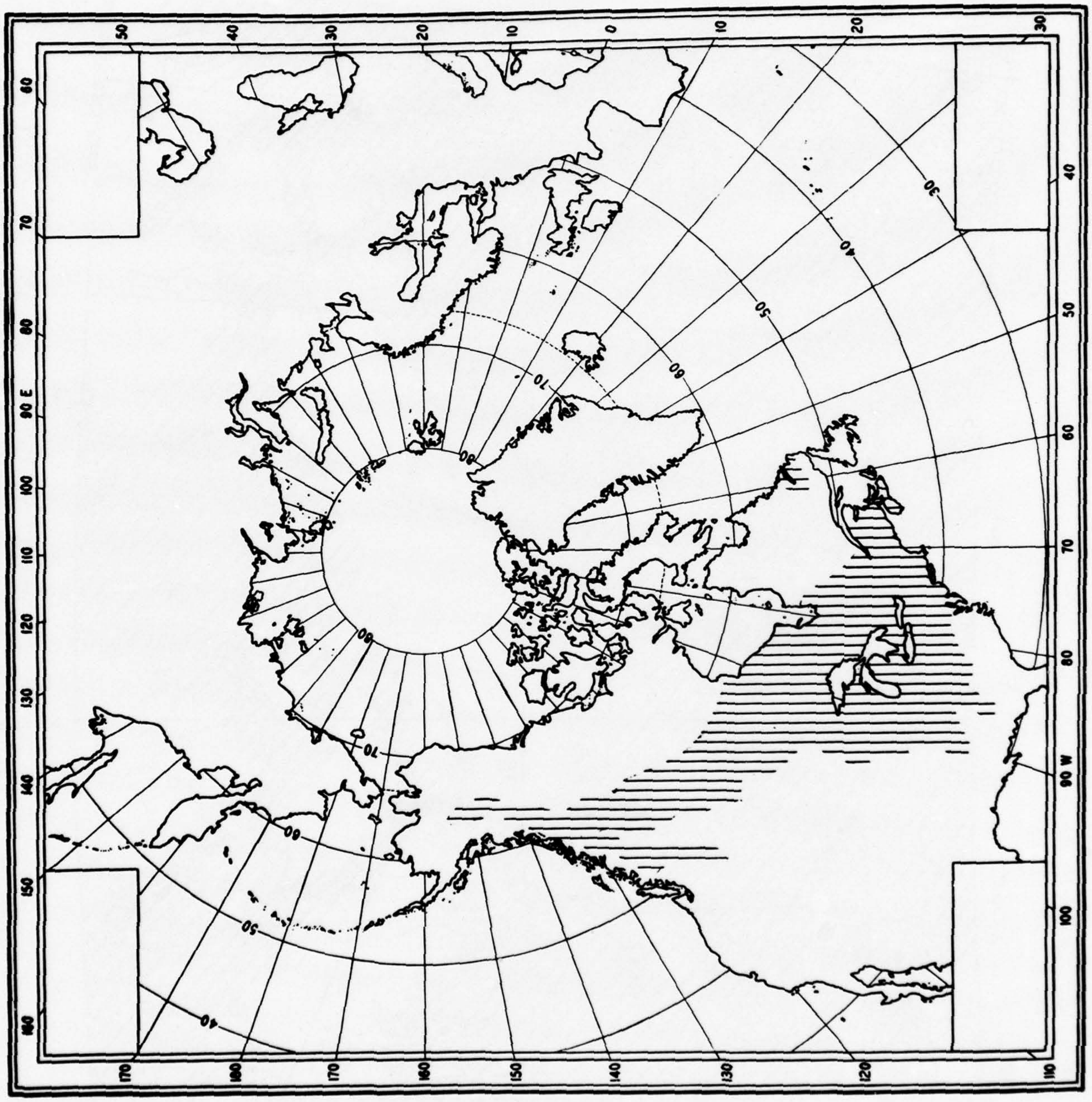
Marmota monax (Maps 37, 38) - The woodchuck scarcely enters our study region. Only a handful of specimens have been collected, all along the valley of the Tanana River or close by. The woodchuck is a herbivore, but because of its rarity in this northern extension of its range, it is relatively unimportant in the taiga food web. Moreover, it is a true hibernator and is thus immobilized and unavailable for most of the year.



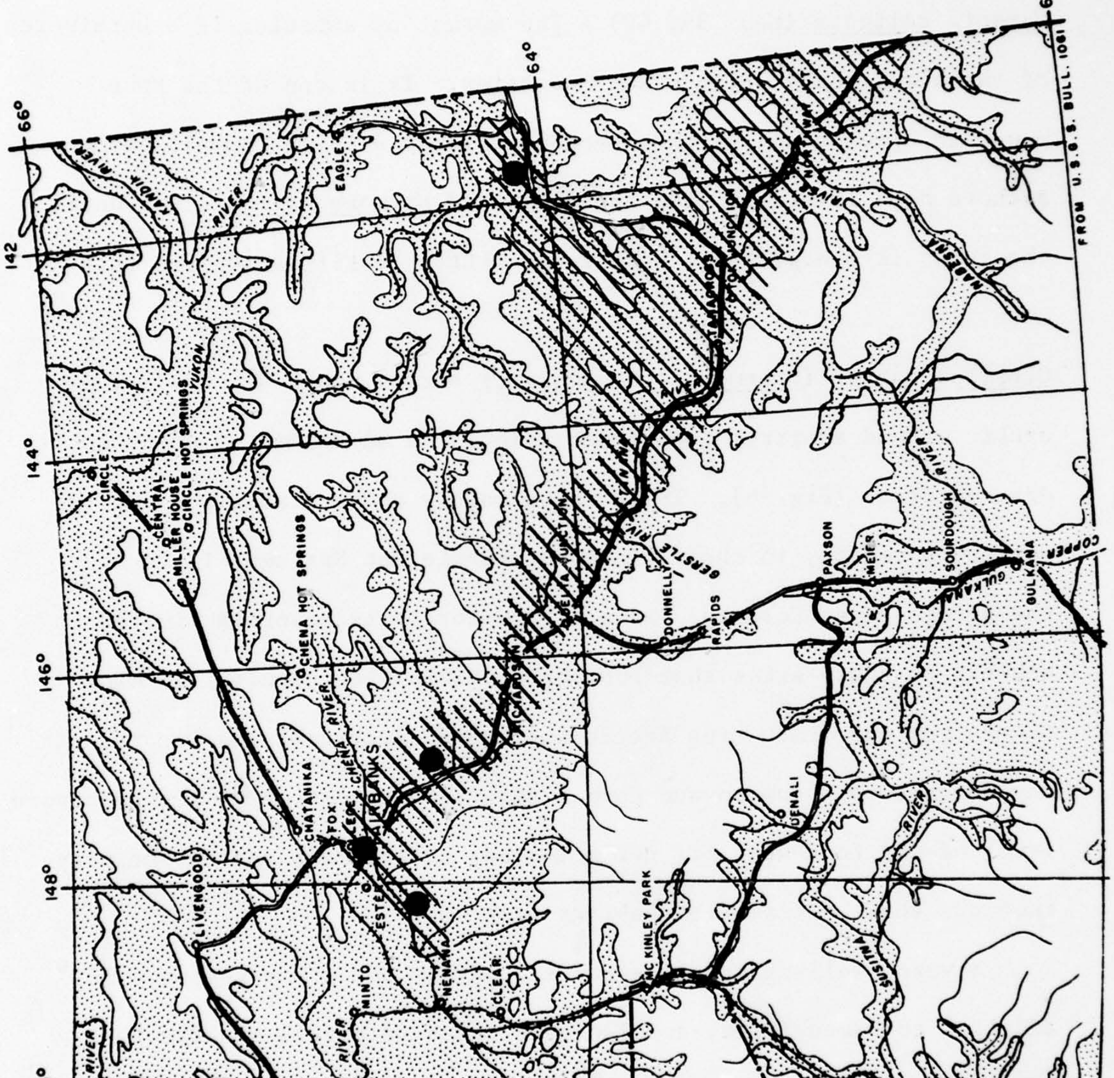
Map 35. Distribution of Lynx canadensis in North America and Lynx lynx in Eurasia.



Map 36. Occurrence of Lynx canadensis in the study region.



Map 37. Distribution of Marmota monax.



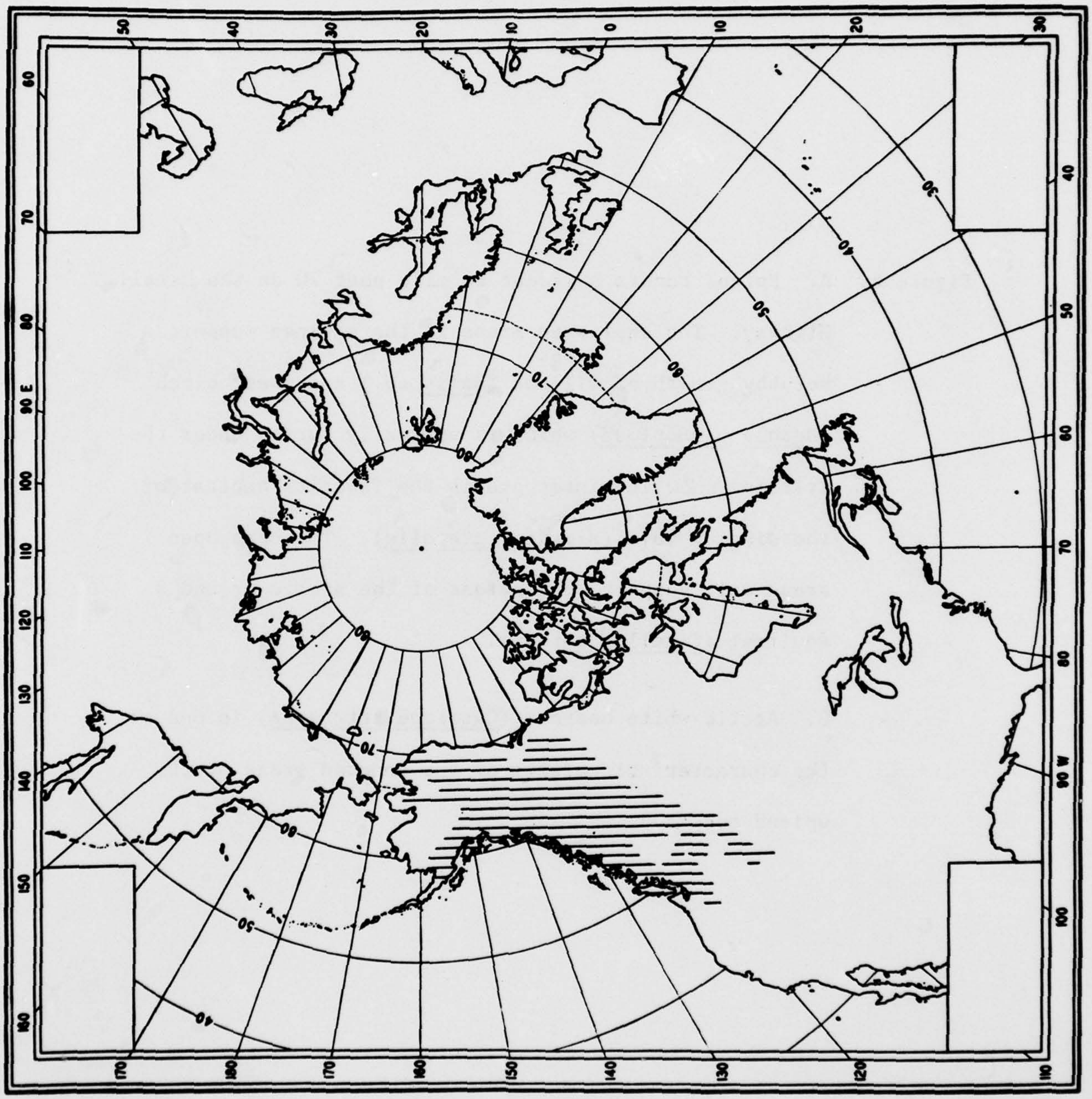
Map 38. Occurrence of Marmota monax in the study region.

Marmota caligata (Maps 39, 40) - The marmot or whistler is a herbivore of the high, rocky uplands and mountains. It is one of the true mountain species and is thus technically not a taiga mammal. Some authors have lumped it with the Old World Marmota marmota, but until the genus is monographed there seems little justification for this move.

Citellus parryi (Spermophilus undulatus auct.) (Maps 41, 42) - The arctic ground squirrel (see frontispiece) is an animal of open, well-drained areas (Fig. 6). It is found mainly above timberline but in our study region, in the vicinity of Circle Hot Springs, it invades the spruce-aspen forests. As a hibernator it is severely limited in habitat to those sites that provide suitable hibernacula. In many tundra regions (both true Arctic tundra and Arctic-Alpine tundra) it may be extremely common and form a significant portion of the herbivore level of the food web. If not molested, individuals may become very tame and share edificarian habitat with man.

Several well-marked subspecies occur in our study region. In addition to named forms, a melanistic phase occurs in the Circle-Circle Hot Springs region. These melanistic animals are exceedingly interesting, since they occur in all gradations from only a slight darkening of the normal color (The subspecies C. p. osgoodi is characterized primarily by an intensification of the buffy underparts to a reddish-orange) to complete black. Concurrent with melanism are marked behavior changes; the animals become extremely shy and wary.

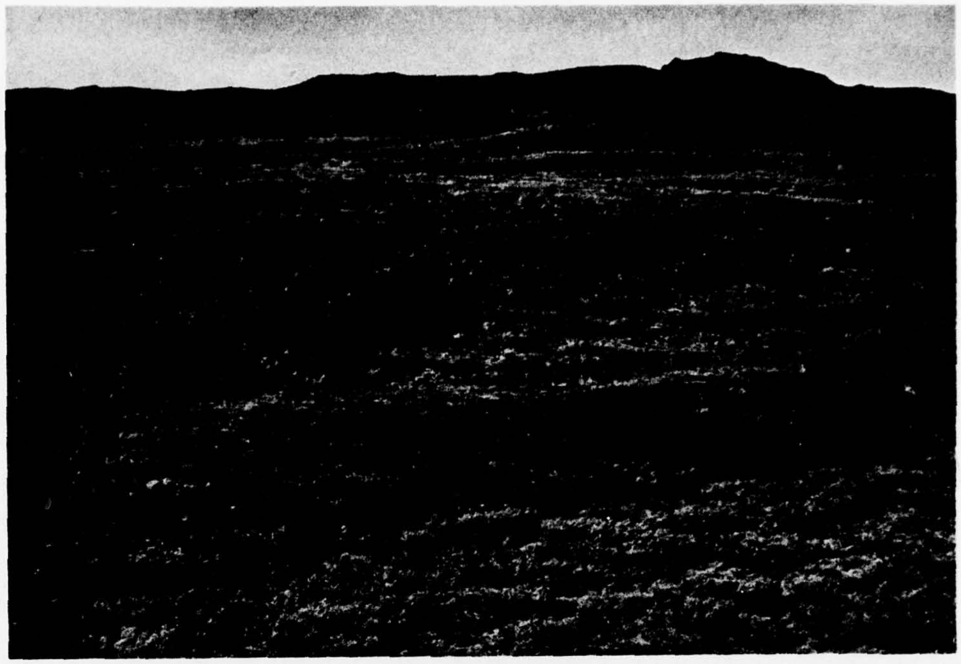
The nomenclatural haze which surrounds this animal reflects its



Map 39. Distribution of Marmota caligata.

Figure 6. A. Upland tundra adjacent to mile post 70 on the Denali Highway. The sheltered areas in the ravines support a scrubby growth of willows (*Salix* sp.) and dwarf birch (*Betula glandulosa*) which is virtually buried under the drifting snow in winter and is the favorite habitat of the singing vole (*Microtus gregalis*). The more open areas will support populations of the arctic ground squirrel (*Citellus parryi*).

B. Arctic white heather (*Cassiope tetragona*) is one of the characteristic plants of the snowbed areas of the upland tundra.



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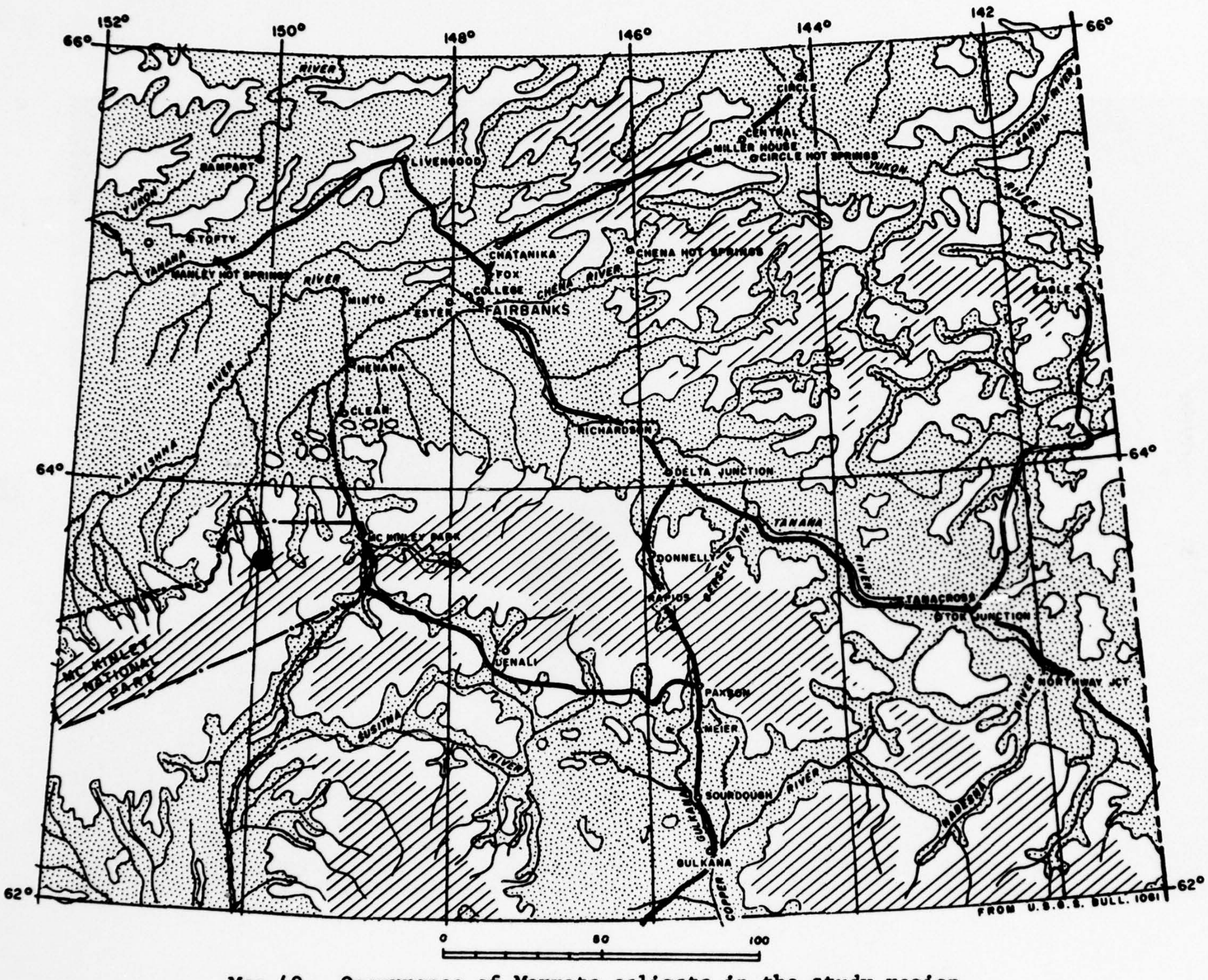
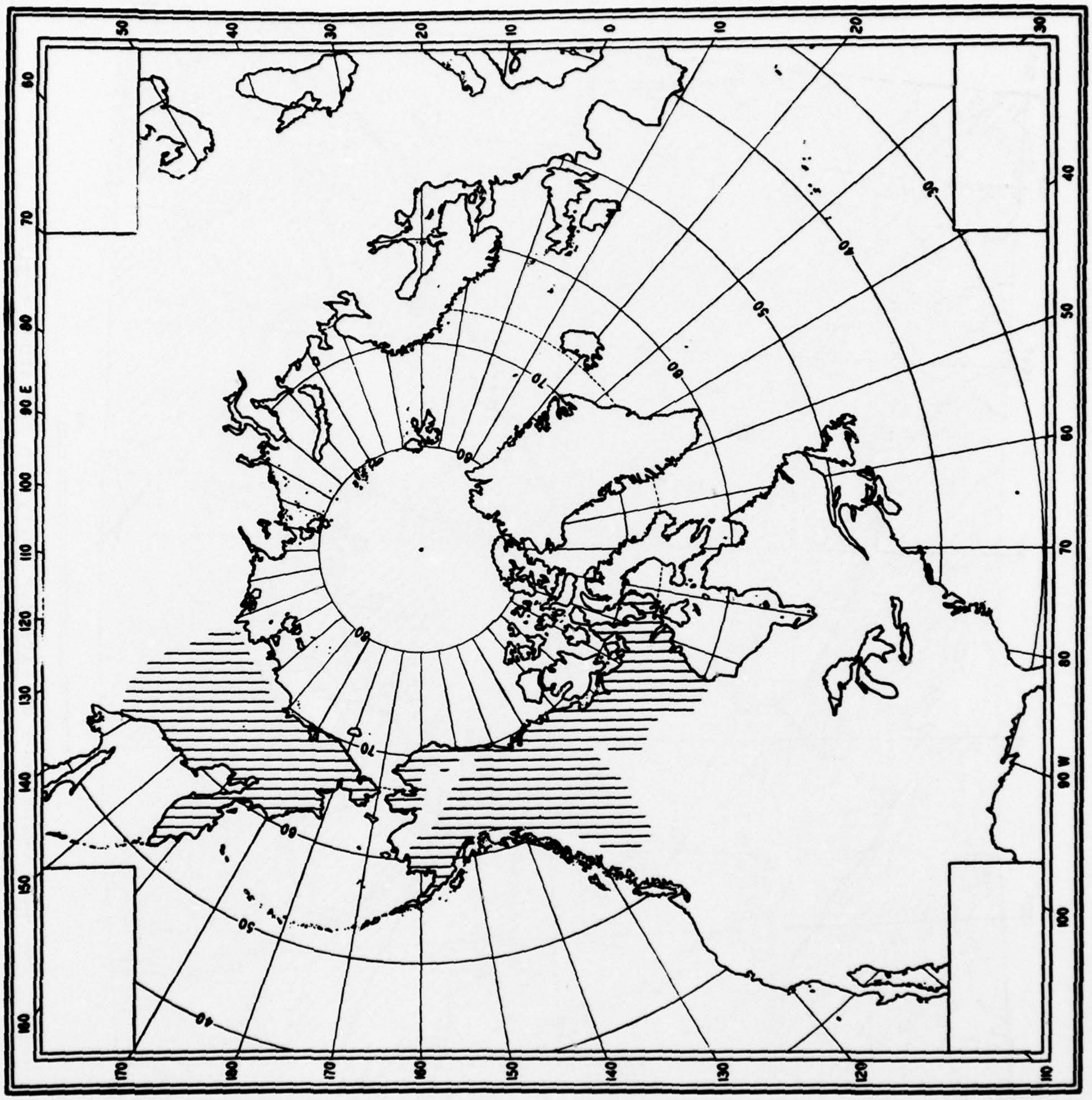
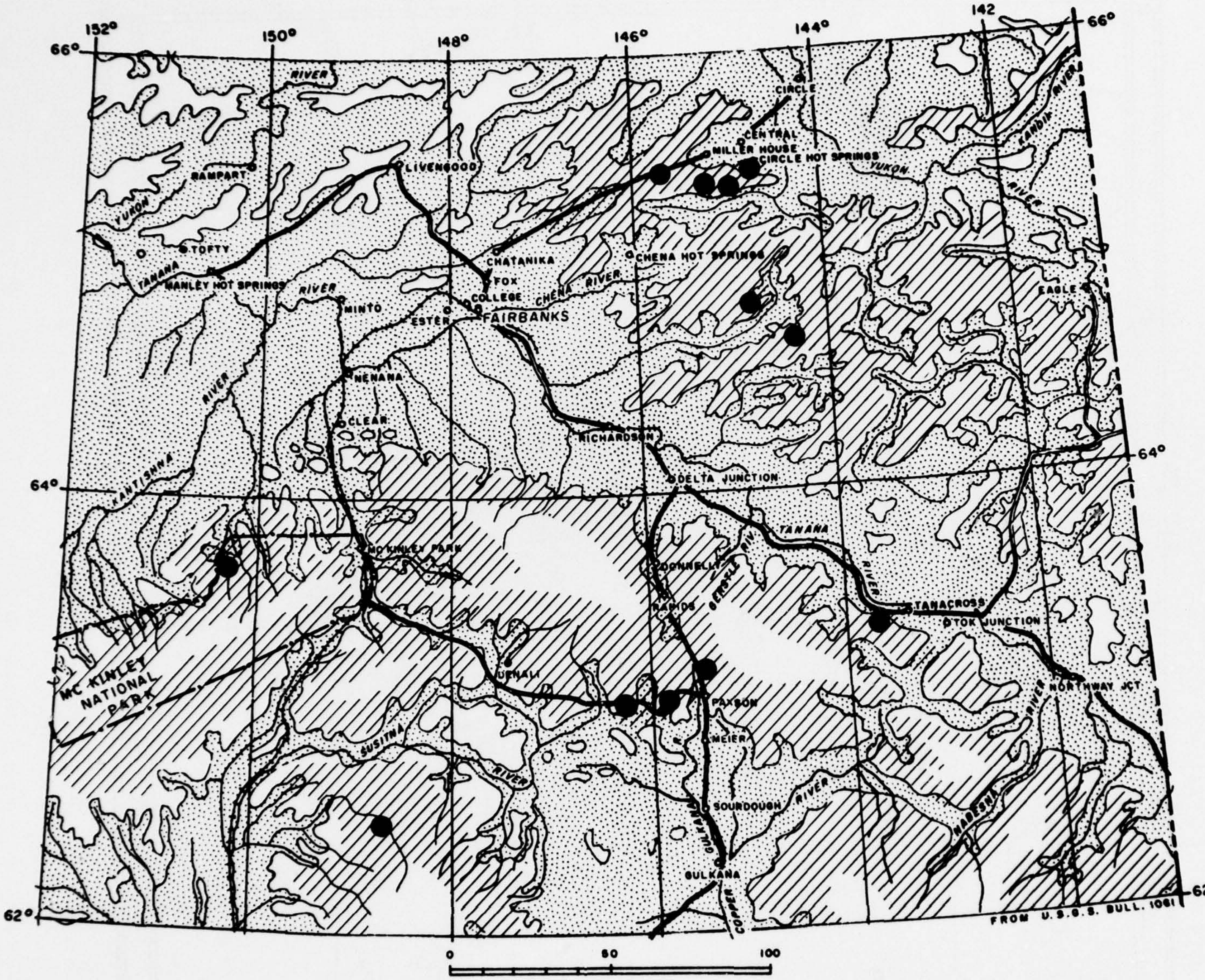


Map 40. Occurrence of Marmota caligata in the study region.



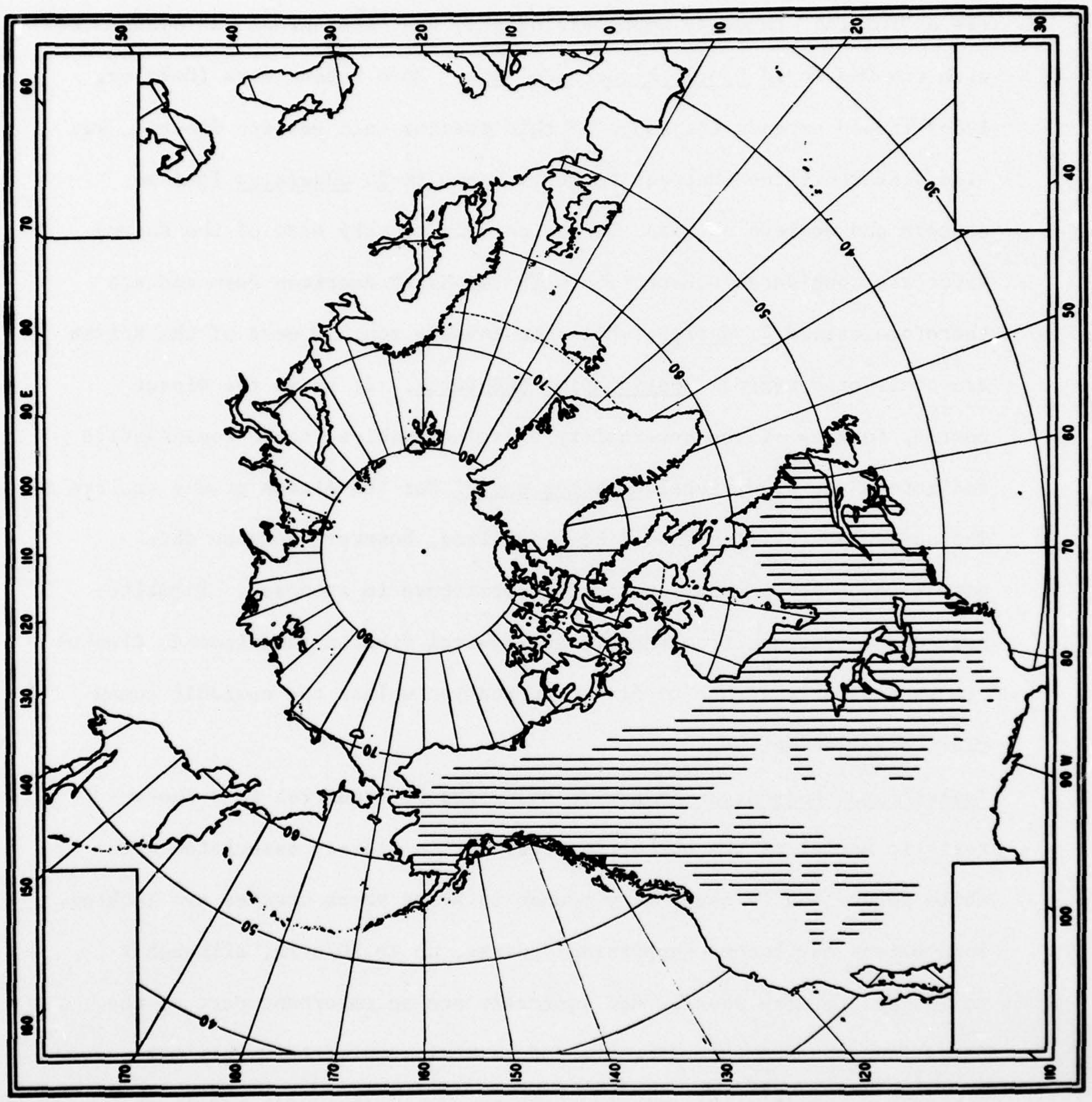
Map 41. Distribution of <u>Citellus</u> <u>parryi</u> in North America and Eurasia.



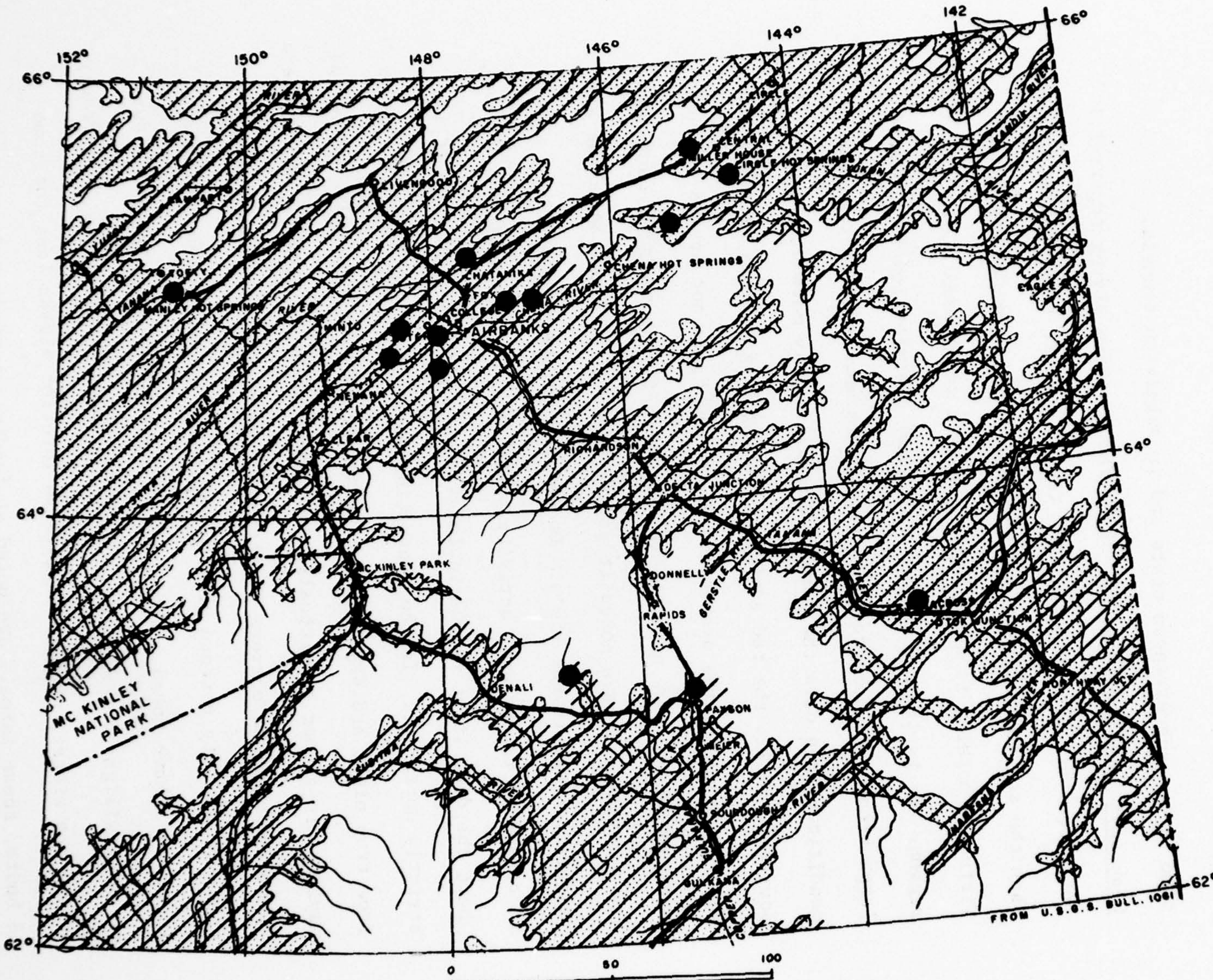
Map 42. Occurrence of <u>Citellus parryi</u> in the study region.

wide range and propensity for differentiation. For some years there was a "lumping" tendency among biologists, and this animal was synonymized with the Old World Spermophilus undulatus. More recent work (Sokolov, 1963) indeed extends the range of this species into eastern Siberia, but also differentiates what was formerly known as S. undulatus into an eastern and western species. Those animals roughly east of the Kolyma River are considered conspecific with the North American form and are therefore called C. parryi, while the animals roughly west of the Kolyma are considered typical Spermophilus undulatus. It seems the wisest course, in view of the uncertainty of relationships, to be conservative and retain the traditional Citellus parryi for the Alaska ground squirrels. The nomenclatural flux should be recognized, however, because this animal is of considerable potential importance in zoonoses. Parasite-host determinations from eastern and central Siberia (and indeed, Alaska) are particularly liable to misinterpretation unless the unstable nomenclature is recognized.

Tamiasciurus hudsonicus (Maps 43, 44) - The red squirrel is a characteristic mammal of the boreal forests. It is closely associated with white spruce and is never very common in areas where spruces are lacking. Populations may become surprisingly dense, up to 10/acre, although 1 to 3/acre are more usual. Red squirrels are an important part of the taiga food web and enter the diet of several carnivores. They make arboreal nests (Fig. 9) and also subterranean nests under and in the midden. These nests are usually heavily populated with fleas. During periods of temperatures below -25 or -30°F., the squirrels spend their



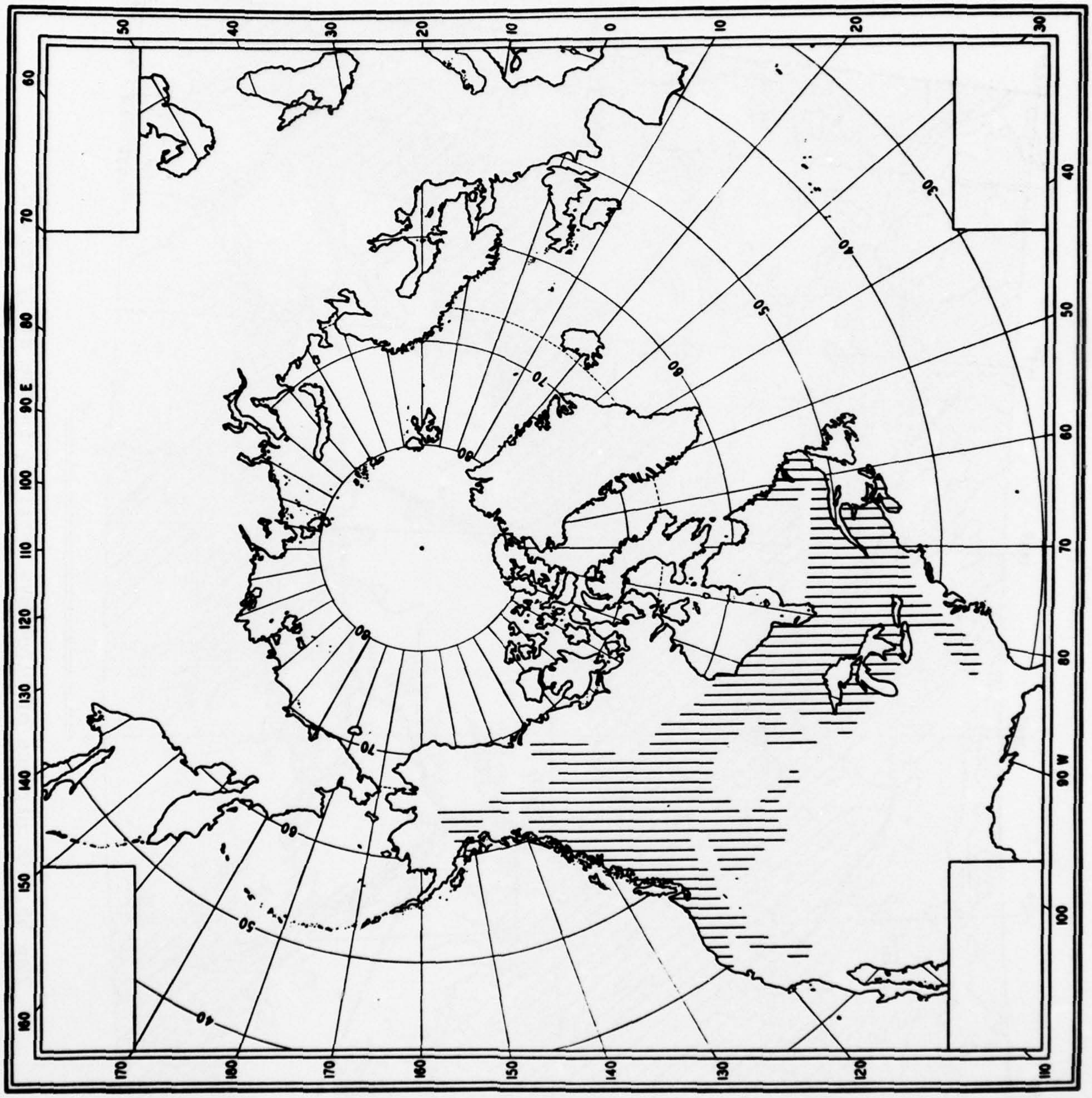
Map 43. Distribution of Tamiasciurus hudsonicus.



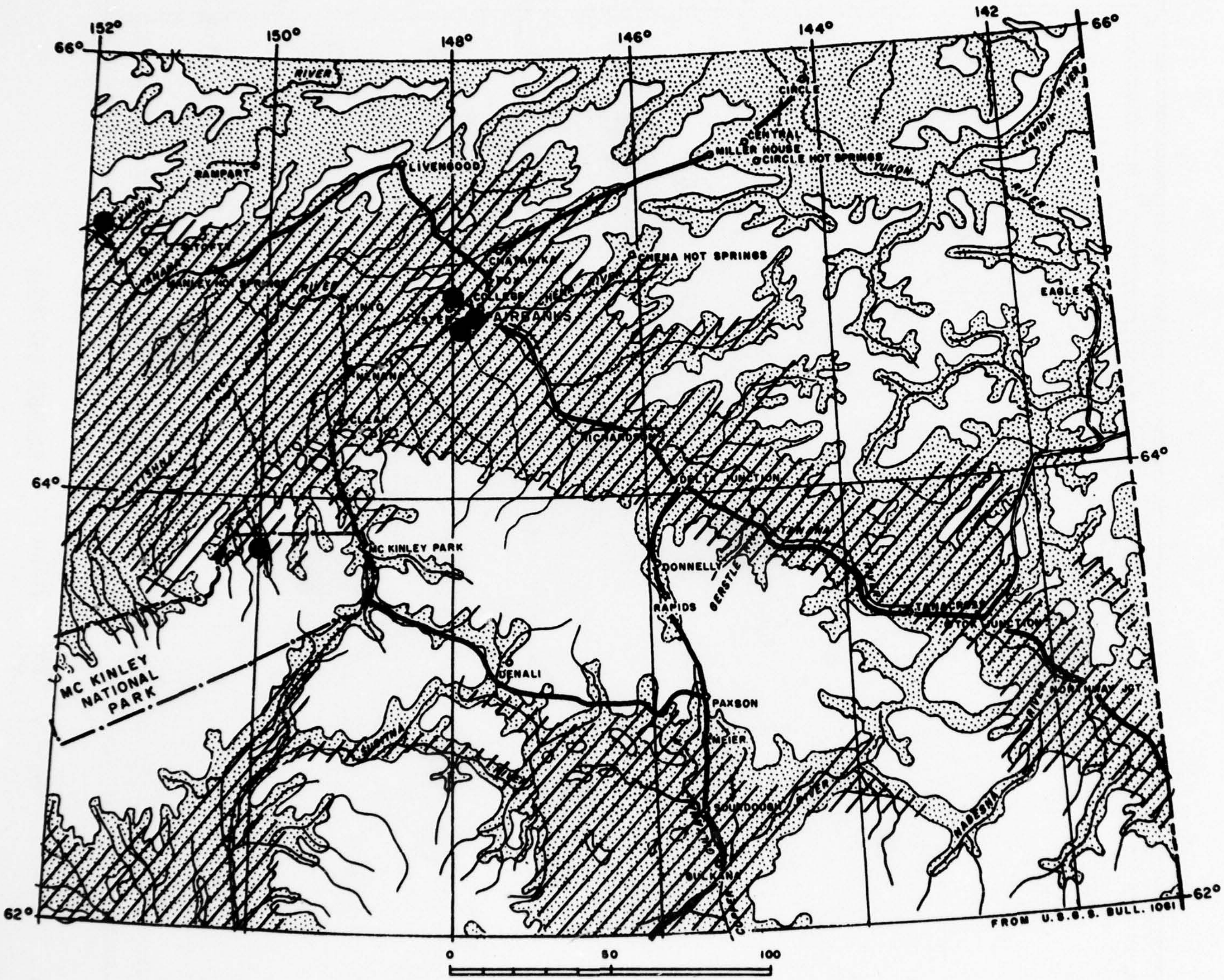
Map 44. Occurrence of <u>Tamiasciurus</u> <u>hudsonicus</u> in the study region.

time in the subterranean nests and in subnivean tunnels.

Glaucomys sabrinus (Maps 45, 56) - The northern flying squirrel is not often collected in our study region, but it is probably more common than the scarce specimens would suggest. It is nocturnal and shy. Virtually nothing is known about its nest or general biology in this region. It is limited in its ecological distribution to areas of large trees. In some respects it appears more adapted to taiga conditions than does the more common and vastly more visible red squirrel. While the red squirrel, during long periods of the winter when the temperatures are below -25 or -30°F, is not active in the trees or on the snow surface, the northern flying squirrel continues its activity. I have noted it active a number of times when the air temperature was in the -50's. One of the interesting problems still to be solved is its diel activity patterns. In more southern regions, where the diel light regime includes true night and daylight, it is strictly nocturnal. In the subarctic, where the light regime varies from true night and daylight in spring and fall to virtually continuous daylight in summer to virtually continuous night in winter, the northern flying squirrel encounters conditions that must place severe stress upon any activity pattern governed by intensity of incident light. In summer I have noted it active only during the brief period of dusk or semi-twilight for an hour or so either side of midnight. Conversely, during the winter, when the nights in interior Alaska last for some 18 hours, these animals are noted at feeding stations as early as 9 or 10 o'clock in the evening. A number of questions immediately arise,



Map 45. Distribution of Glaucomys sabrinus.



Map 46. Occurrence of <u>Glaucomys</u> <u>sabrinus</u> in the study region.

among them, how do individuals manage to acquire enough calories during such a short period of activity to last them for the remainder of the diel cycle? One of the questions stemming from its activity in very cold weather has been partly answered by unpublished work by Dr. Eleanor Viereck. She found, by using an infra-red scanning camera, that the fur of Glaucomys must be many times more efficient as an insulator than the fur of Tamiasciurus. At least, the infra-red scanner showed that Tamiasciurus lost heat relatively uniformly over its body while Glaucomys did not do so, and lost heat to any great extent only through its eyes, ears, and nose.

Castor canadensis (Maps 47, 48) - The beaver is not a typical taiga mammal. Originally its range covered most of North America. It is considered a northern mammal today only because here in the taiga is its last stronghold after many years of exploitation for its fur. In our study region, beavers may be found on virtually any stream, particularly those in which the current is rather sluggish and those that do not carry a great load of glacial silt. The beaver is an economically important fur-bearer; prices range from as low as $4 for a small ungraded pelt to as much as $30 for super-blanket size. If proper hydrological conditions permit, beavers may be found above treeline. Here they subsist in bank houses and feed on willows and even herbaceous vegetation.

Peromyscus maniculatus (Map 49) - The deer mouse is included in most accounts of interior Alaska solely on the basis of a sight record many years ago by Dixon (1938) in Mount McKinley National Park. I

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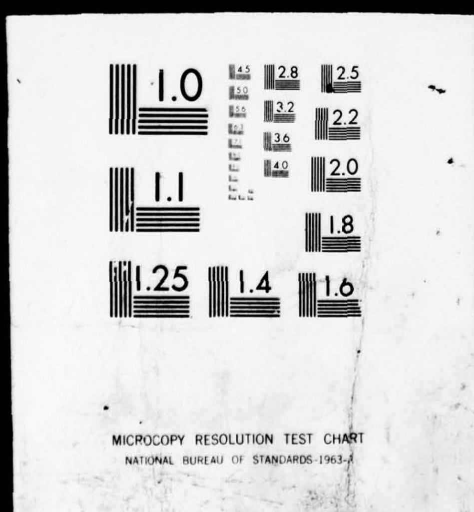
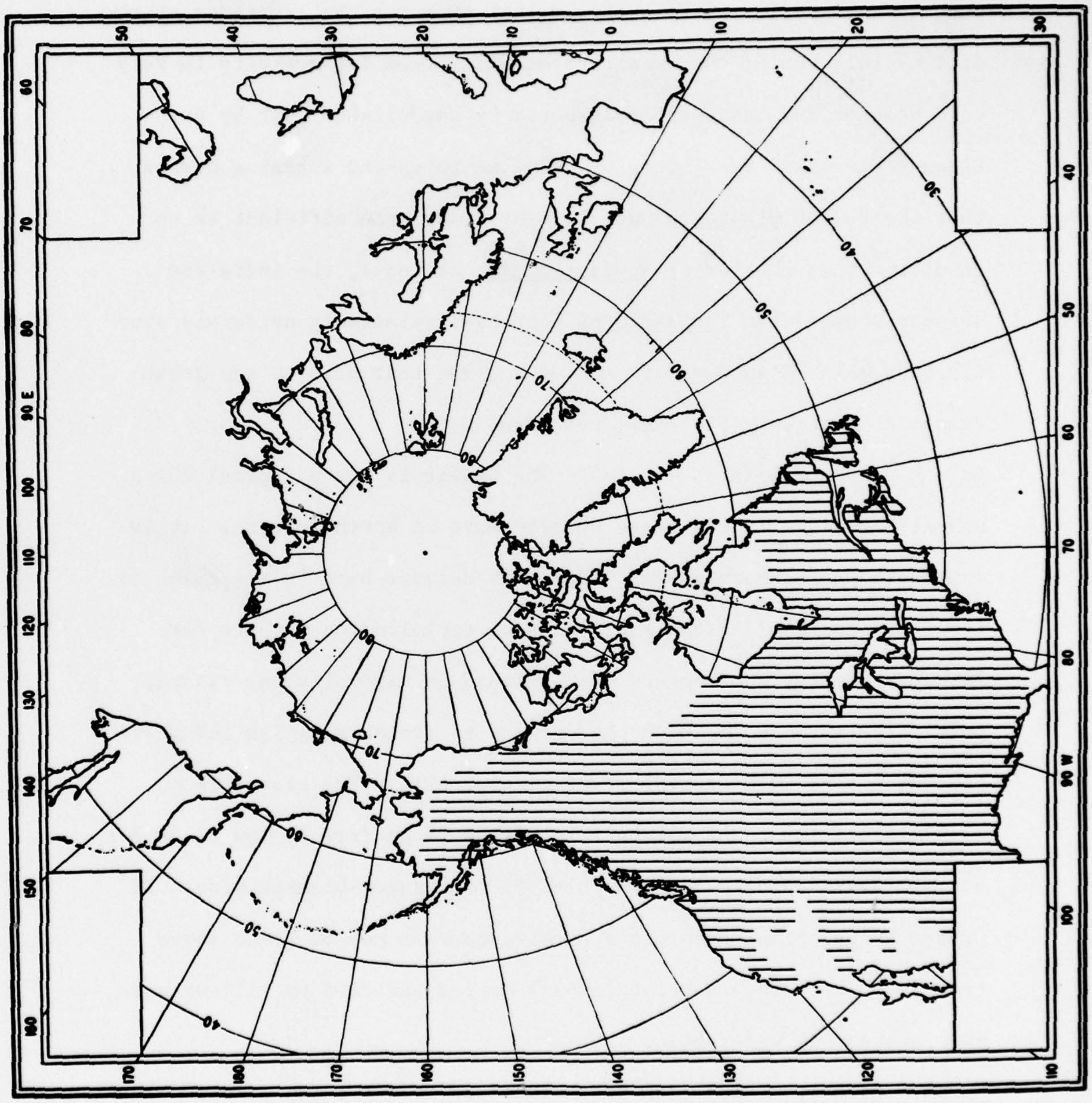
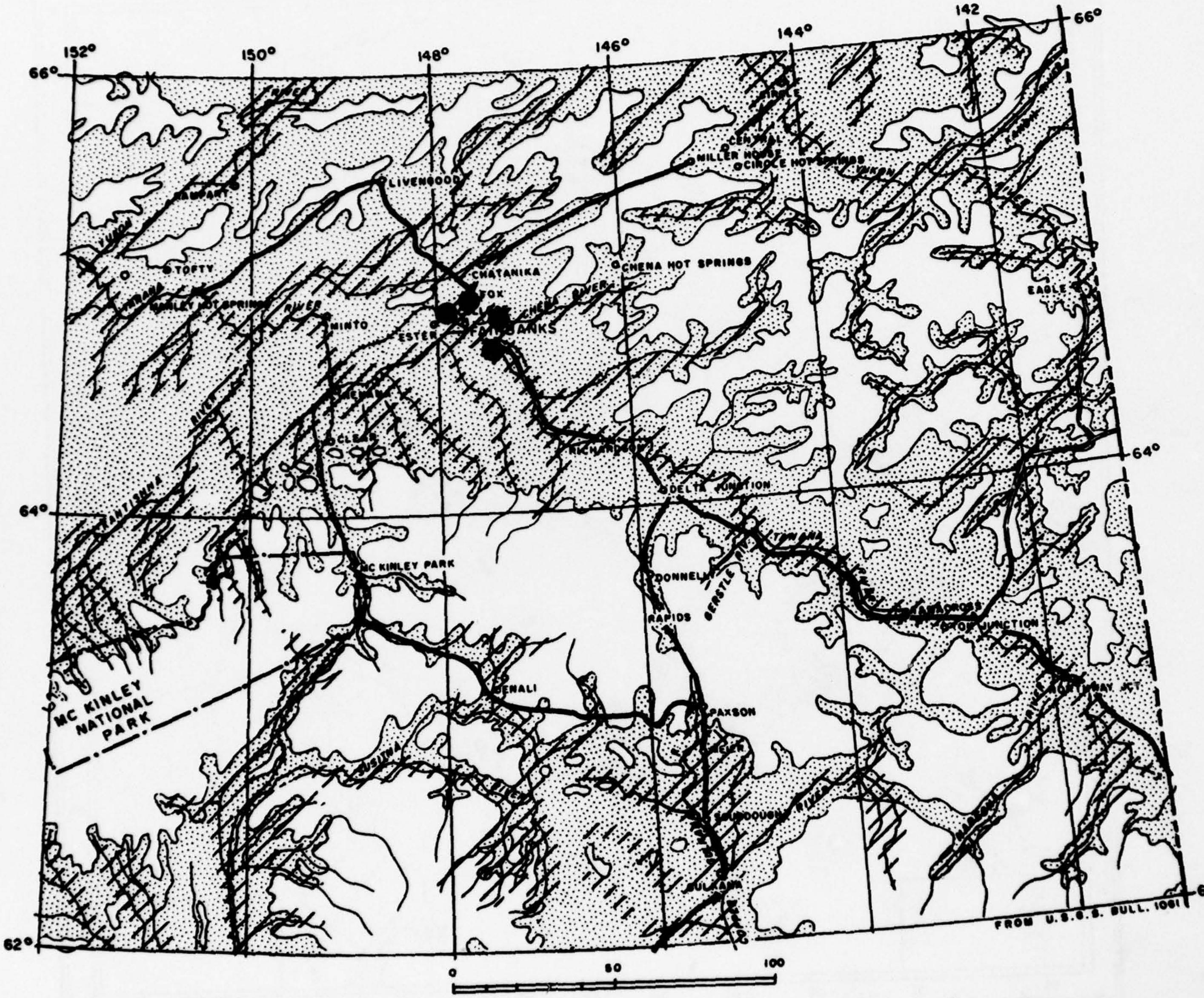
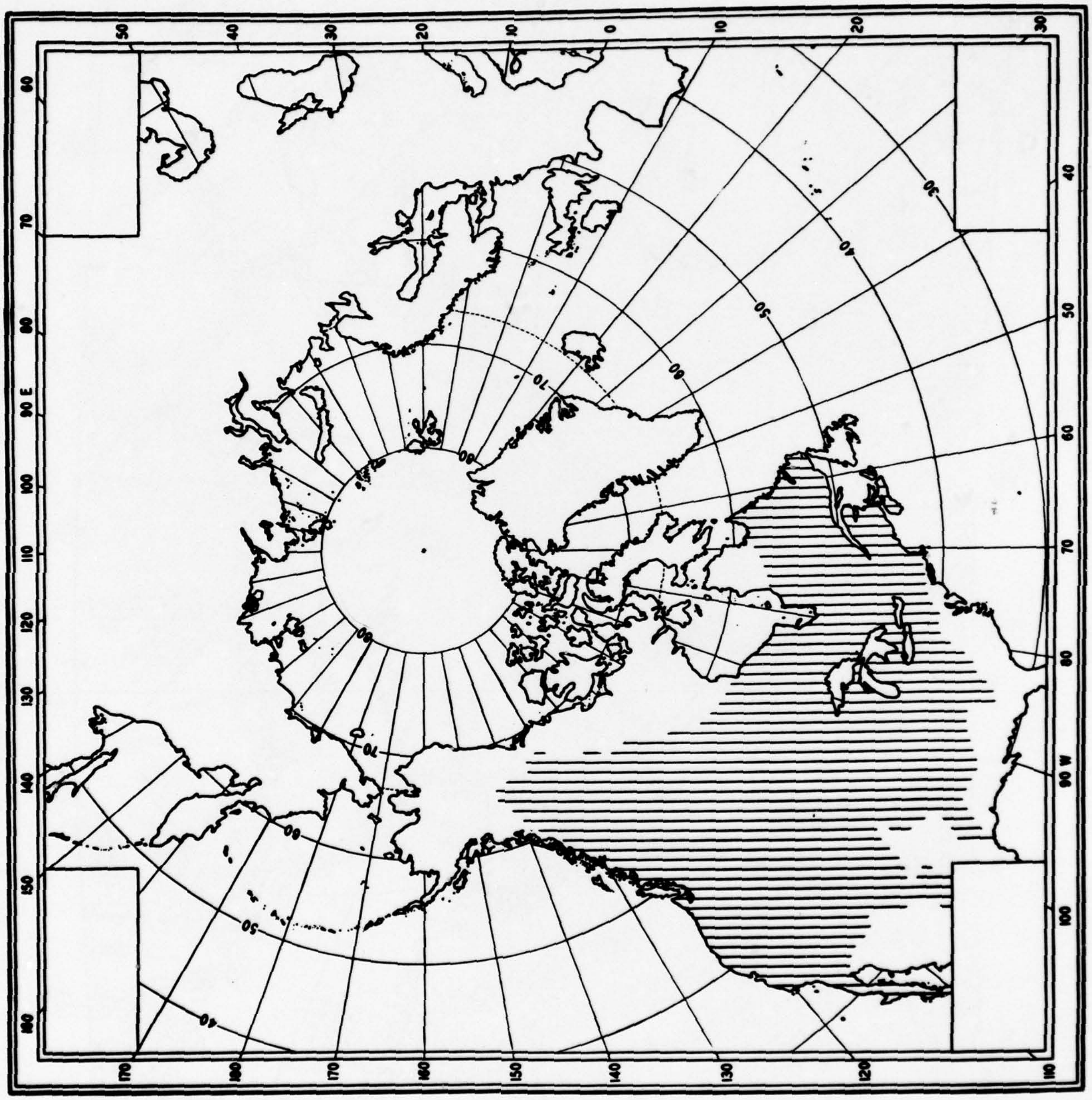




Map 47. Distribution of Castor canadensis.



Map 48. Occurrence of Castor canadensis in the study region.

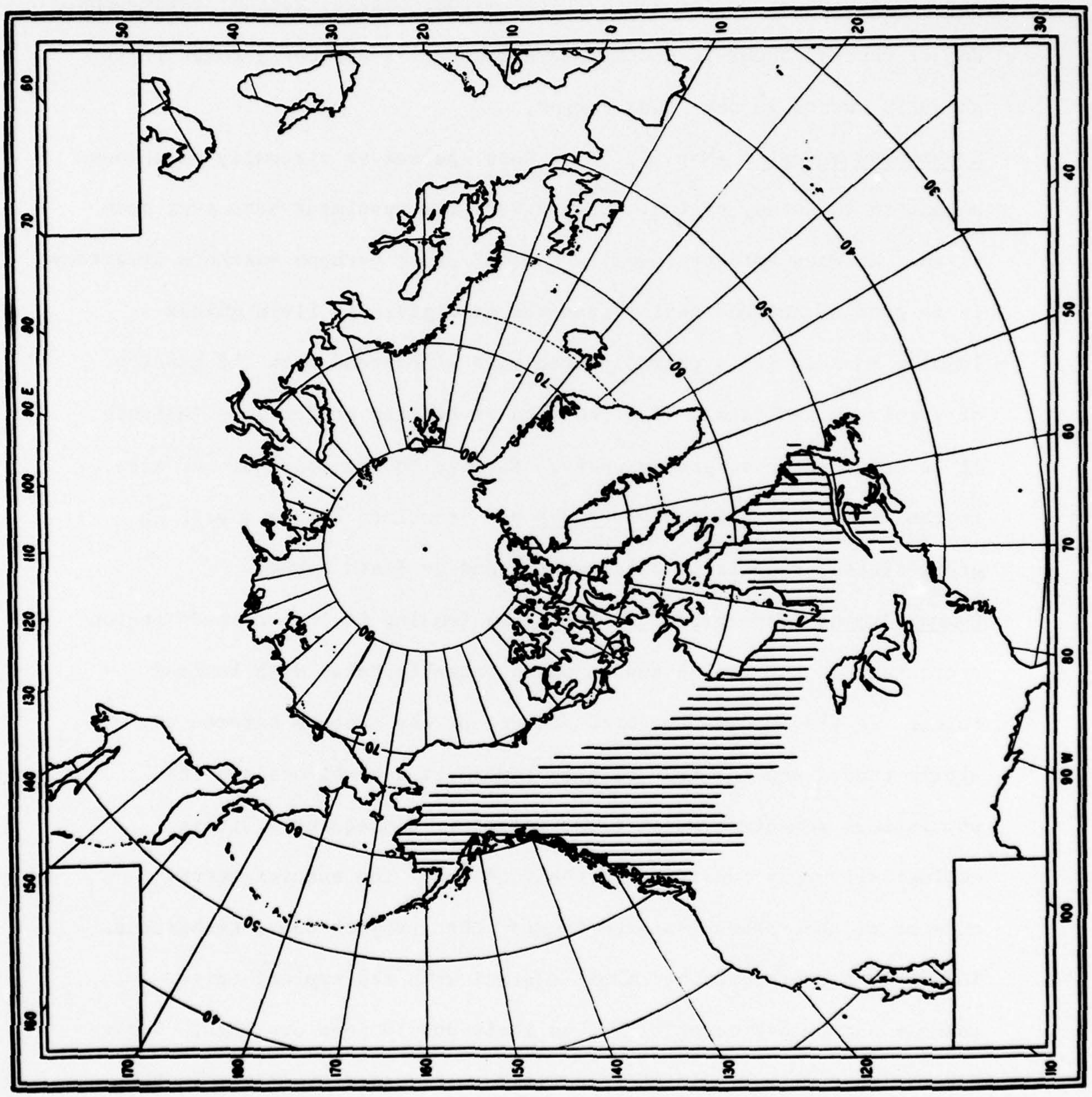


Map 49. Distribution of Peromyscus maniculatus.

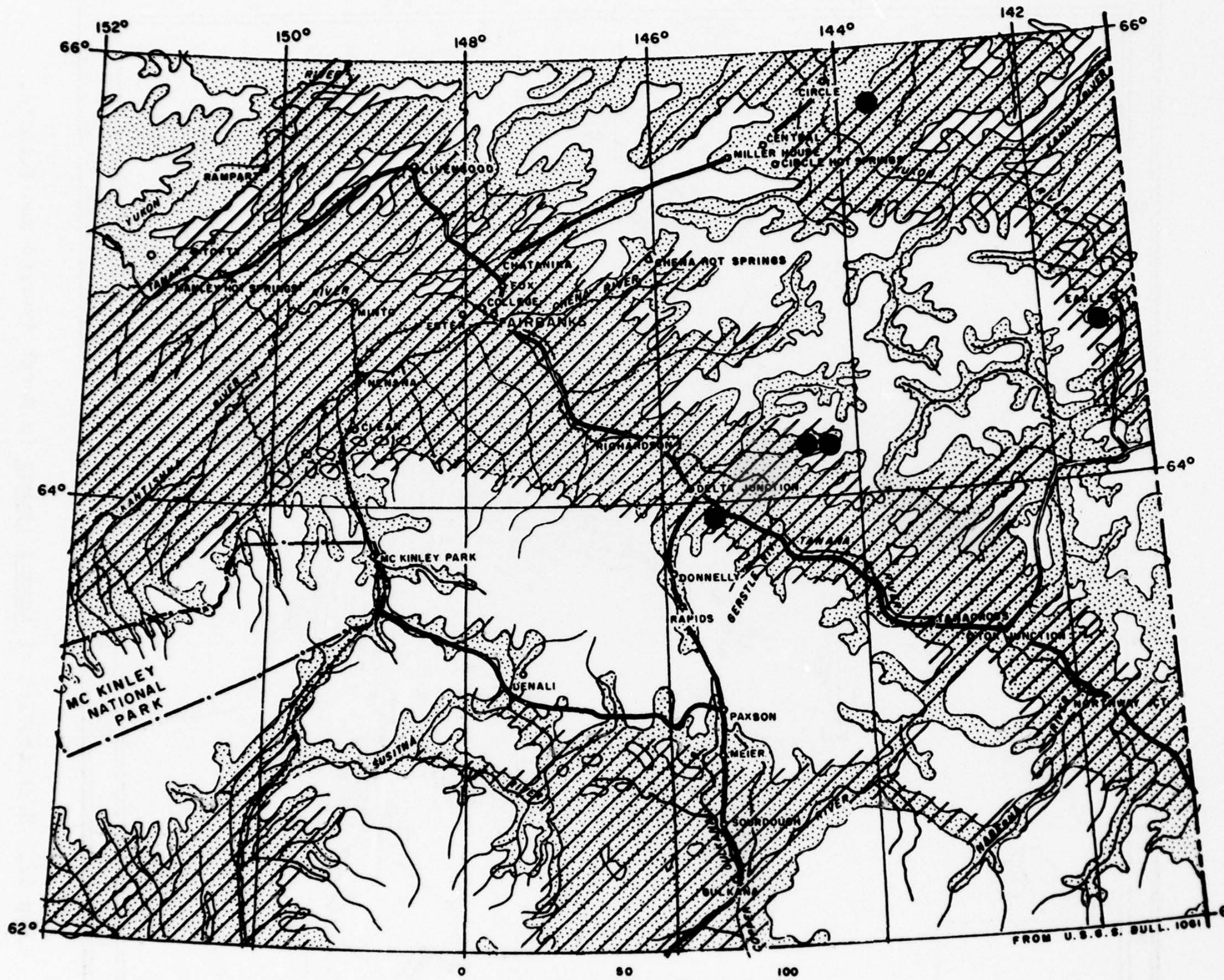
know of no specimen ever having been taken in our study region. It may perhaps occur to the south in the milder coastal region; Peromyscus do, of course, occur in southeastern Alaska. I seriously doubt if it actually occurs in our study region.

Synaptomys borealis (Map 50, 51) - This species is virtually an unknown animal in our study region. Only a very few specimens have ever been taken. It does not even have a "common" name; perhaps northern synaptomys is as good as any and better than the name given in field guides -- lemming mouse. It is probably much more widespread than the paucity of specimens indicates. The few data on habitat preferences indicate it is found in dense grassy areas. Not far to the south of our area, in the Matanuska valley, Synaptomys has sometimes become a pest in grain fields, especially those surrounded by dense berms.

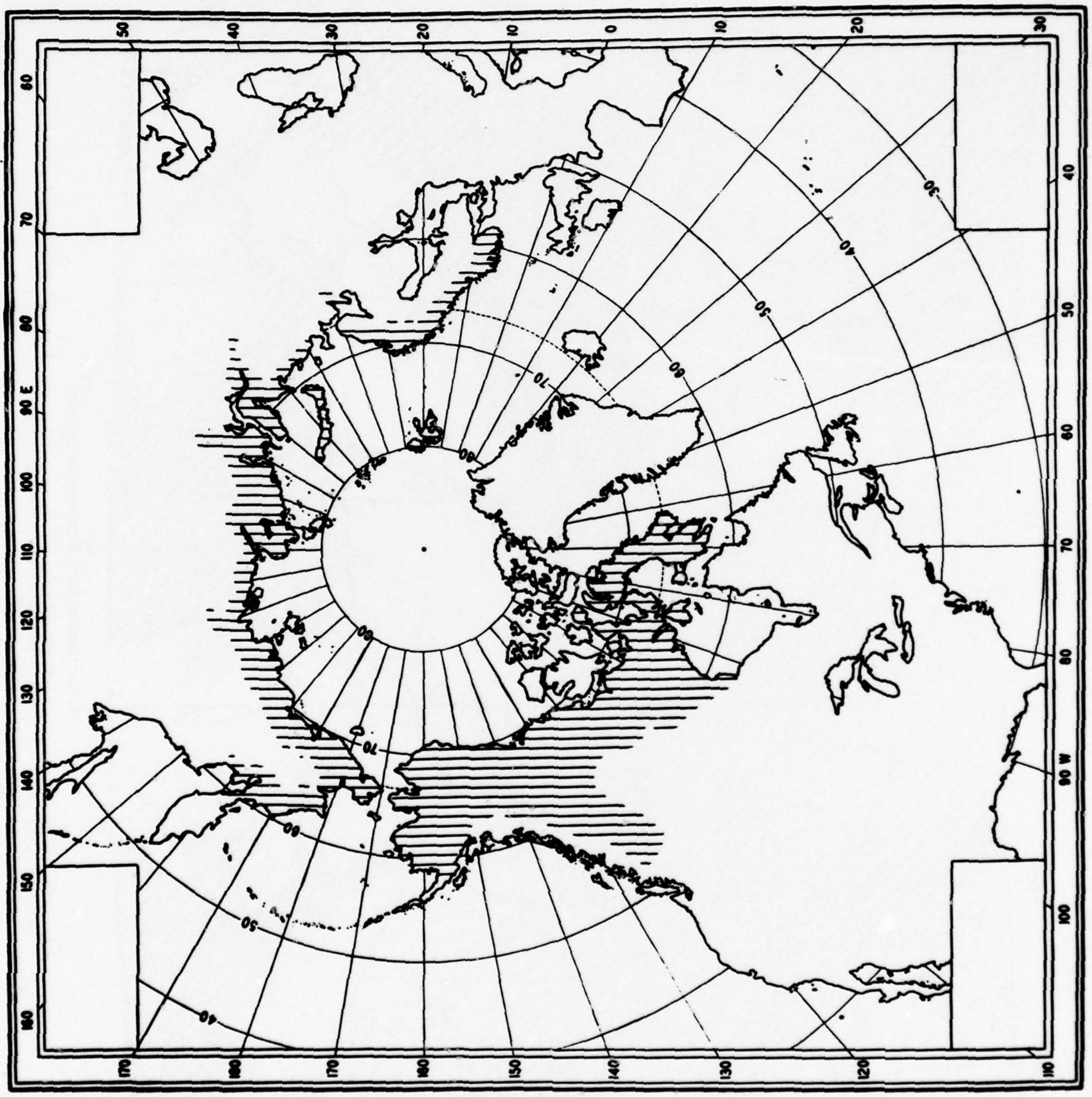
Lemmus lemmus (Maps 52, 53) - The brown lemming is in our study region a creature of the alpine tundra which interdigitates with lowland taiga. It also occurs in forest-tundra or the ecotone between the alpine tundra and the true taiga. Lemmus is a herbivore and its populations sometimes reach great density. Consequently, it is ecologically very important in the food web. The species occurs on some of the rather isolated "domes" that project above timberline. Thus they are brought into close contact with the typical taiga mammals and birds, especially when their populations are high. Their population cycles run in the classic 3 to 4 year frequency. In the Alaska Range they are closely associated with Clethrionomys rutilus and Microtus gregalis, but in more northern regions they are associated



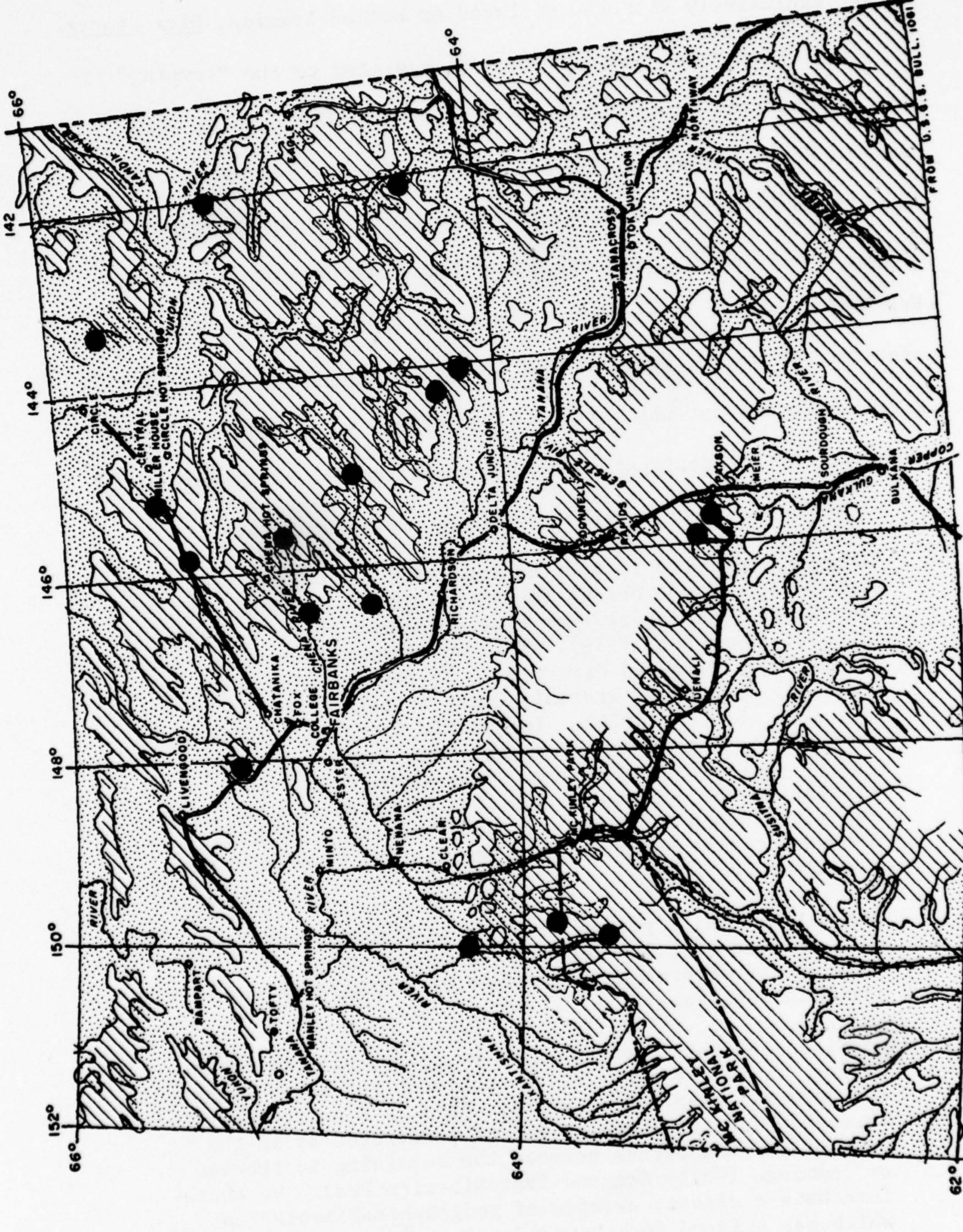
Map 50. Distribution of Synaptomys borealis.



Map 51. Occurrence of Synaptomys borealis in the study region.



Map 52. Distribution of Lemmus lemmus in North America and Eurasia.



Map 53. Occurrence of Lemmus lemmus in the study region.

almost exclusively with the collared or hoofed lemming, Dicrostonyx.

In recent years those biologists addicted to the "lumping" process referred to earlier have synonymized this species with the Old World Lemmus sibiricus, mainly by intuition without benefit of critical examination of specimens. Recently Sidorowicz (1960, 1964) has examined specimens from both the Old World and New World and has indeed found the brown lemmings to be the same species. He found, however, that Lemmus sibiricus itself was not a valid species but was part of a larger and more complex species. Thus the correct designation of the brown lemming is Lemmus lemmus.

Sidorowicz's conclusions are worth repeating here:

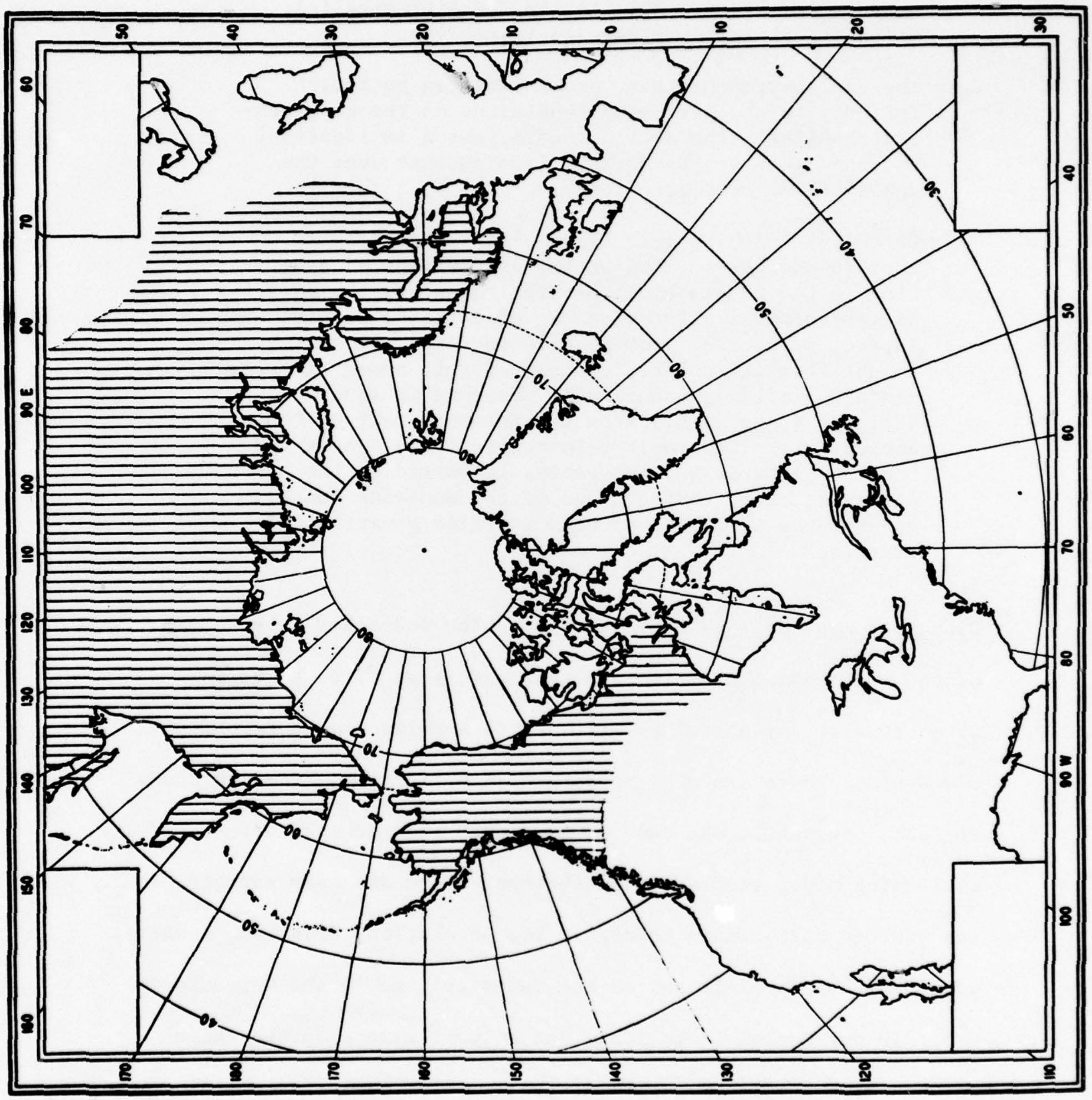
> "Lemmings migrated to America from Asia during the Pleistocene period across the bridge formed by the land of Alaska and Siberia, which at that time connected these two continents (Hamilton, 1939). This was a migration of lemmings in an eastward direction. To the west lemmings reached, in Europe, Ireland, Great Britain, the Pyrennes and Alps (Hinton, 1926). In Siberia there is a relict form of lemming described as the Amur lemming, Lemmus lemmus amurensis Vinogradov, 1924, known from a few specimens, the systematic position of which is not fully explained (Sidorowicz, 1960). On this account I have not given this form in the list of lemming subspecies.
>
> After the glacial period, lemmings in Europe, retreating with the receding ice-sheet, reached the areas which they occupy at present (mountains of Scandinavia and the Kola Peninsula).
>
> American lemmings are separated by the relatively narrow Bering Straits from the Asian continent and have been so for several thousands of years. This is a natural barrier through which the lemmings cannot penetrate, as in the case of the boundaries between the remaining subspecies of lemmings (White Sea and East Siberian Sea). We therefore have a classic example of geographical isolation which has existed for thousands of years. No new forms

have, however, been formed here - the lemmings from each side of the Bering Straits do not differ significantly in any respect (morphologically and biologically), cross-breeding freely between themselves.

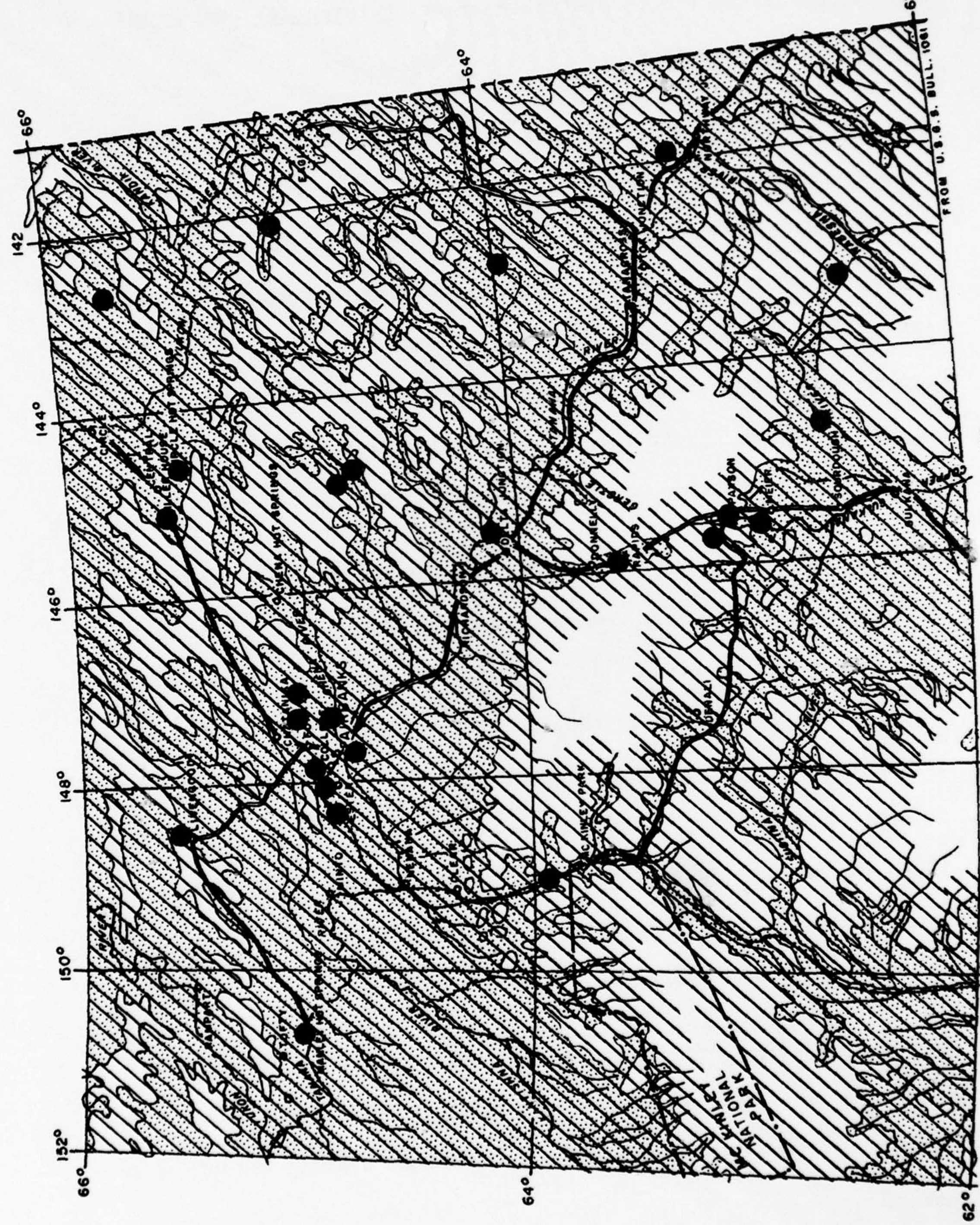
The explanation of this phenomenon can be sought for only in the unvarying conditions of the geographical habitat - the arctic tundra, which is identical on both sides of the Straits (and further over the whole of the arctic regions).

On the strength of this example it may be assumed that in species-forming processes the fact of alteration in the geographical habitat and next, the question of geographical alteration are of decisive significance (apart, of course, from genetic factors). Lemmings do not form an isolated example of this among mammals, since a similar phenomemon is observed in squirrels (*Sciurus vulgaris* L.) from the European part of the Soviet Union (Sidorowicz, in preparation), where the boundary between two subspecies is formed by the type of forest stand northern, and of the moderate zone, and not the existance of some definite geographical barrier."

Clethrionomys rutilus (Maps 54, 55) - The redbacked vole is one of the most common mammals in Alaska and is as close to being ubiquitous as any boreal mammal. It is equally common in the Old World. There are many specimens in collections from our study region; frequently one has to "trap out" the redbacks before collecting other species. Nonetheless, there are many aspects of its biology that remain unknown. Its populations fluctuate greatly, as noted above. It is one of the basic species in the taiga food web. In our region it is found not only in mature spruce taiga but in seral stages as well. It is also common above timberline, as noted above. Its associates on the same trophic level are many; *M. pennsylvanicus* in wet grassy areas, *M. oeconomus* in



Map 54. Distribution of Clethrionomys rutilus in North America and Eurasia.



Map 55. Occurrence of Clethrionomys rutilus in the study region.

subalpine forests and in disturbed areas, M. gregalis and Lemmus lemmus in alpine tundra.

Microtus pennsylvanicus (Maps 56, 57) - The meadow vole, familiar to most temperate zone mammalogists, is also found in our study region. Here in the north it is restricted primarily to wet, grassy areas such as pond borders, old beaver meadows and flooded spits. Its populations, like those of most boreal microtines, undergoes violent numerical fluctuations. I have also taken it in the subalpine spruce forest near Paxson, but only in a wet seepage spot with a dense growth of Ledum.

Microtus oeconomus (Maps 58, 59) - The tundra vole is, next to the redbacked vole, the most common mammal in Alaska. It is found in a wide variety of habitats. It is much less common in mature spruce forest than elsewhere. In the vicinity of Paxson Lake, however, it is the common Microtus along the weedy and brushy road berms and in other ecologically disturbed areas (Fig. 7, 9). It is also found in the open subalpine spruce forests there. Population cycles fluctuate in the classic 3 to 4 year cycle. This species is widely distributed in the Old World.

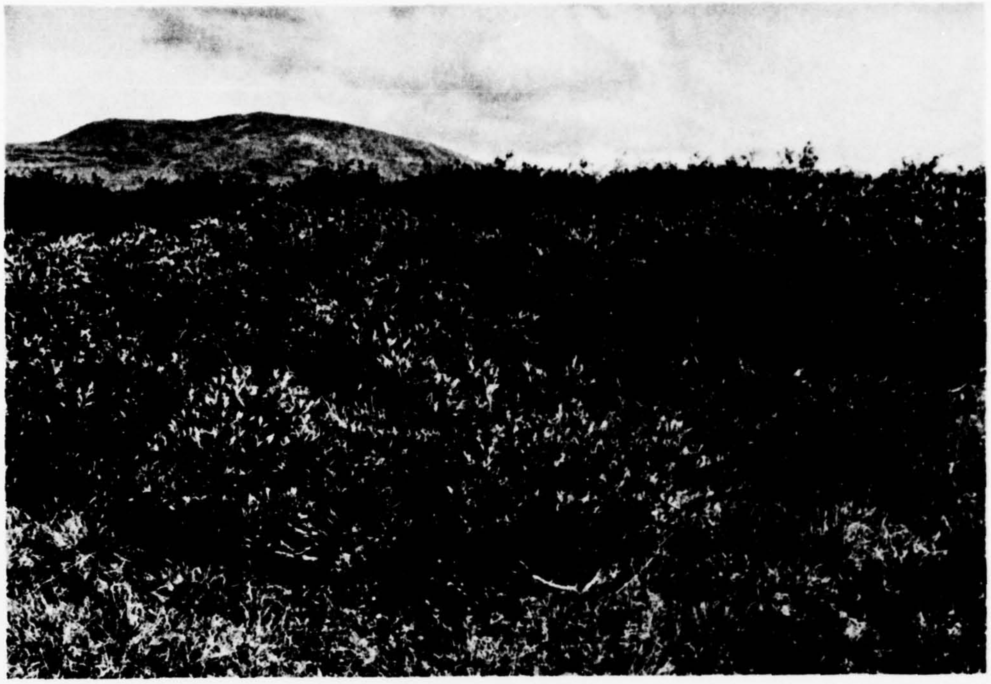
Microtus gregalis (=M. miurus auct.) (Maps 60, 61) - The singing vole (Fig. 8) is a creature of Low Arctic tundra and shrubby alpine tundra. Its distribution appears governed to a great extent by snow cover.

Although populations were very low in 1964 we located several

Figure 7. A feeding station of the tundra vole (Microtus oeconomus). Vegetation consists chiefly on horse-tail (Equisetum) and grass (Calamogrostis sp.). In the subarctic and arctic regions it is often difficult to judge the age of such cuttings. In a moist habitat such as this, cuttings made in late summer or early fall of the previous year frequently appear fresh to the inexperienced person, thereby causing a considerable waste of effort in trapping.

Figure 8. A. Habitat for the singing vole (<u>Microtus gregalis</u>). We found several small pockets on Helmet Mountain near mile post 9 of the Denali Highway which contained dense populations of this microtine.

B. A specimen of the singing vole taken in a snap-trap. Unfortunately, live trapping methods were virtually a failure when attempting to trap this mammal.



A

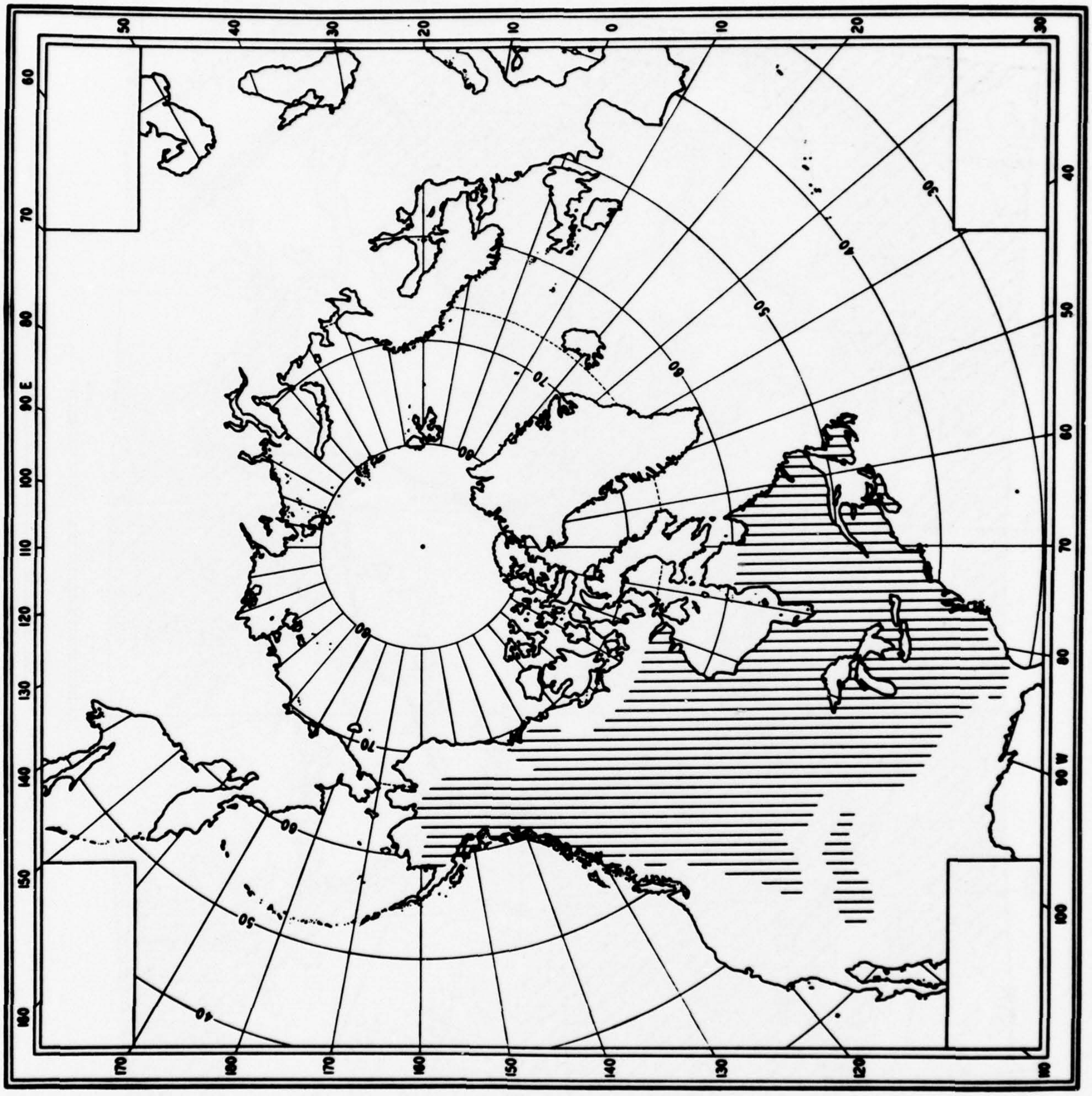
B

Figure 9. A. In ecologically disturbed, well drained areas, dense stands of grass, mostly Calamogrostis canadensis occur. Such stands of grass provide a favorable habitat for the tundra vole (Microtus oeconomus).

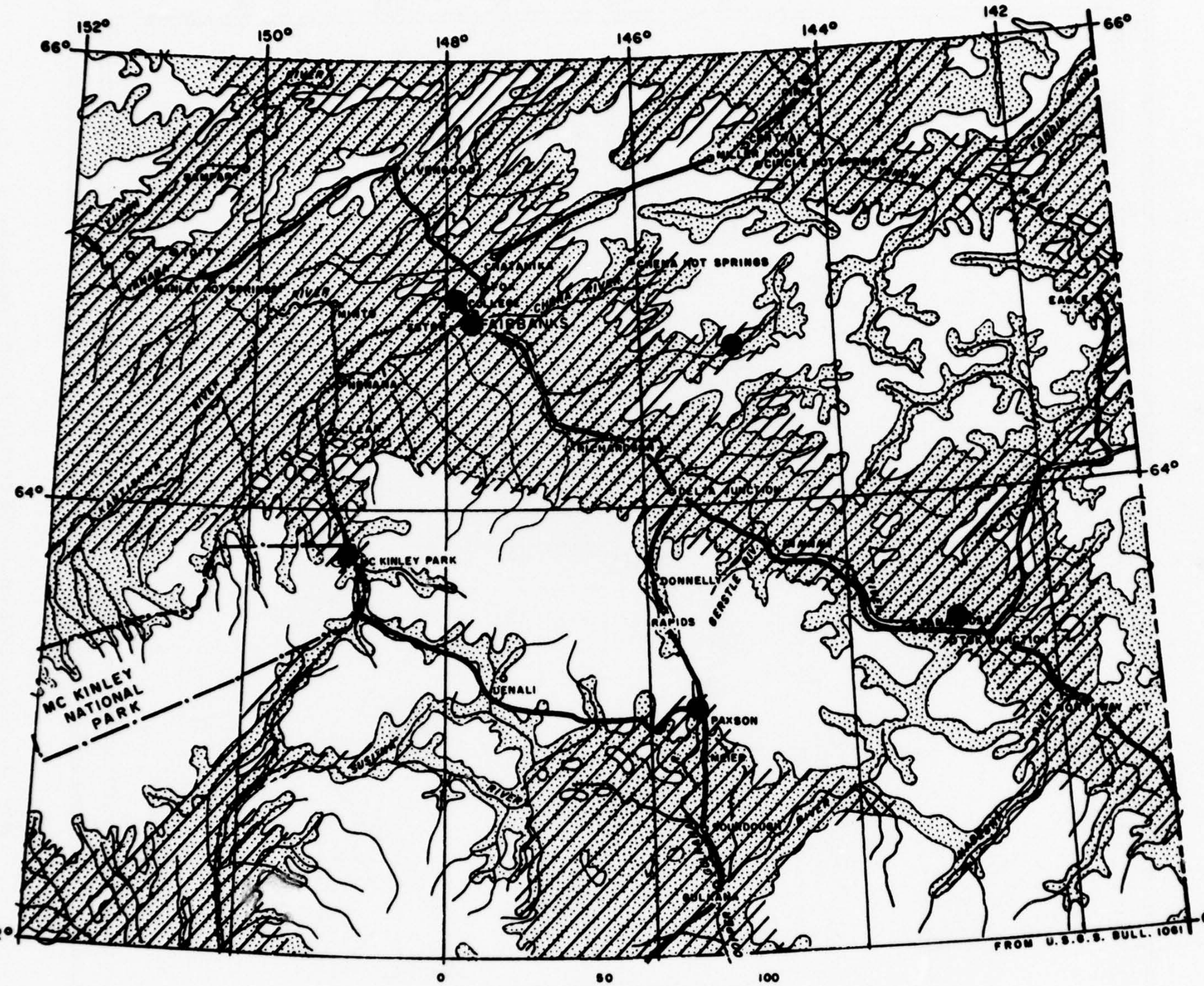
B. Nest of the red squirrel (Tamiasciurus hudsonicus) is frequently a rich source of ectoparasites, particularly fleas. As yet no ticks have been recovered from the nests of this animal.

A

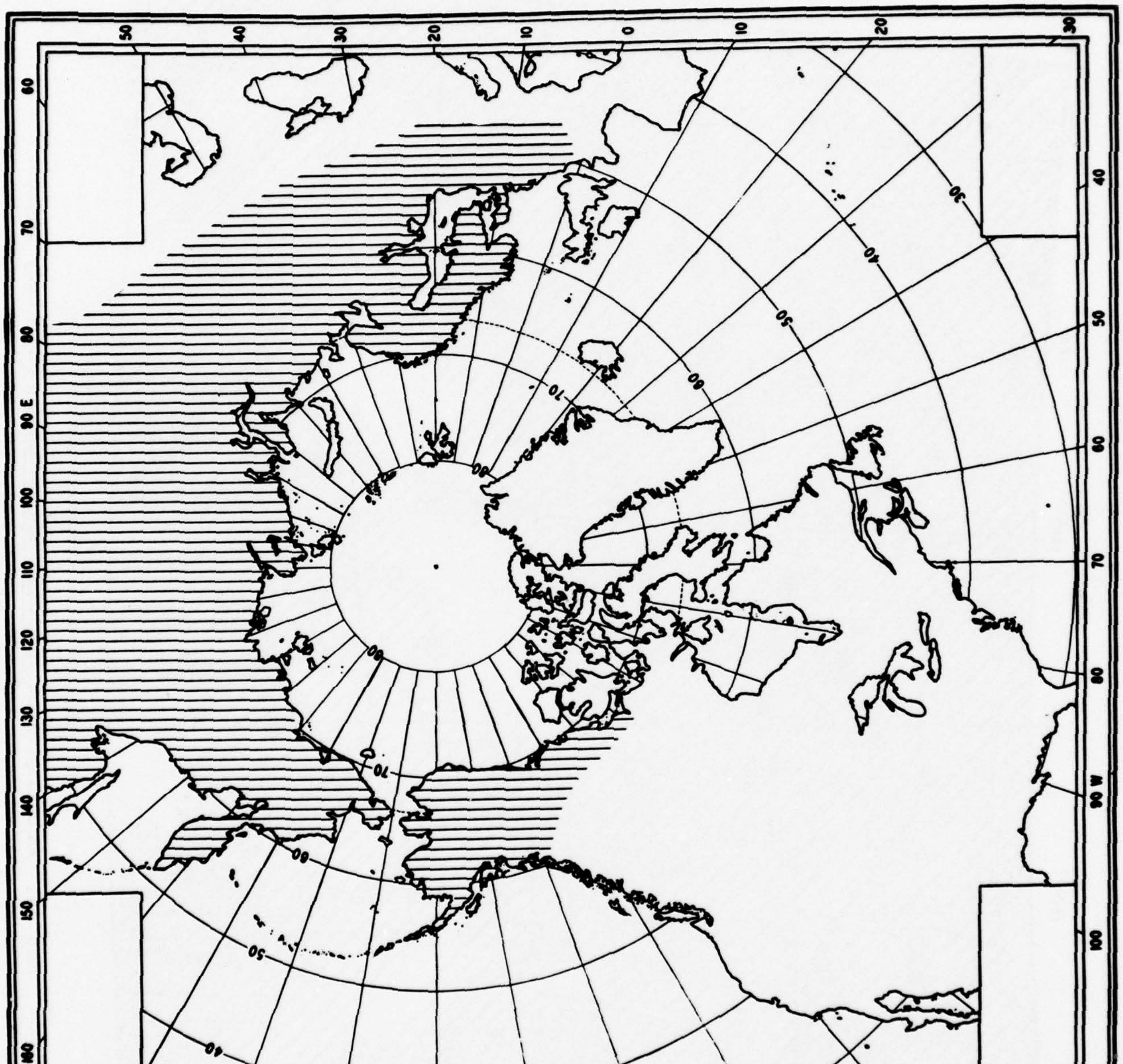
B



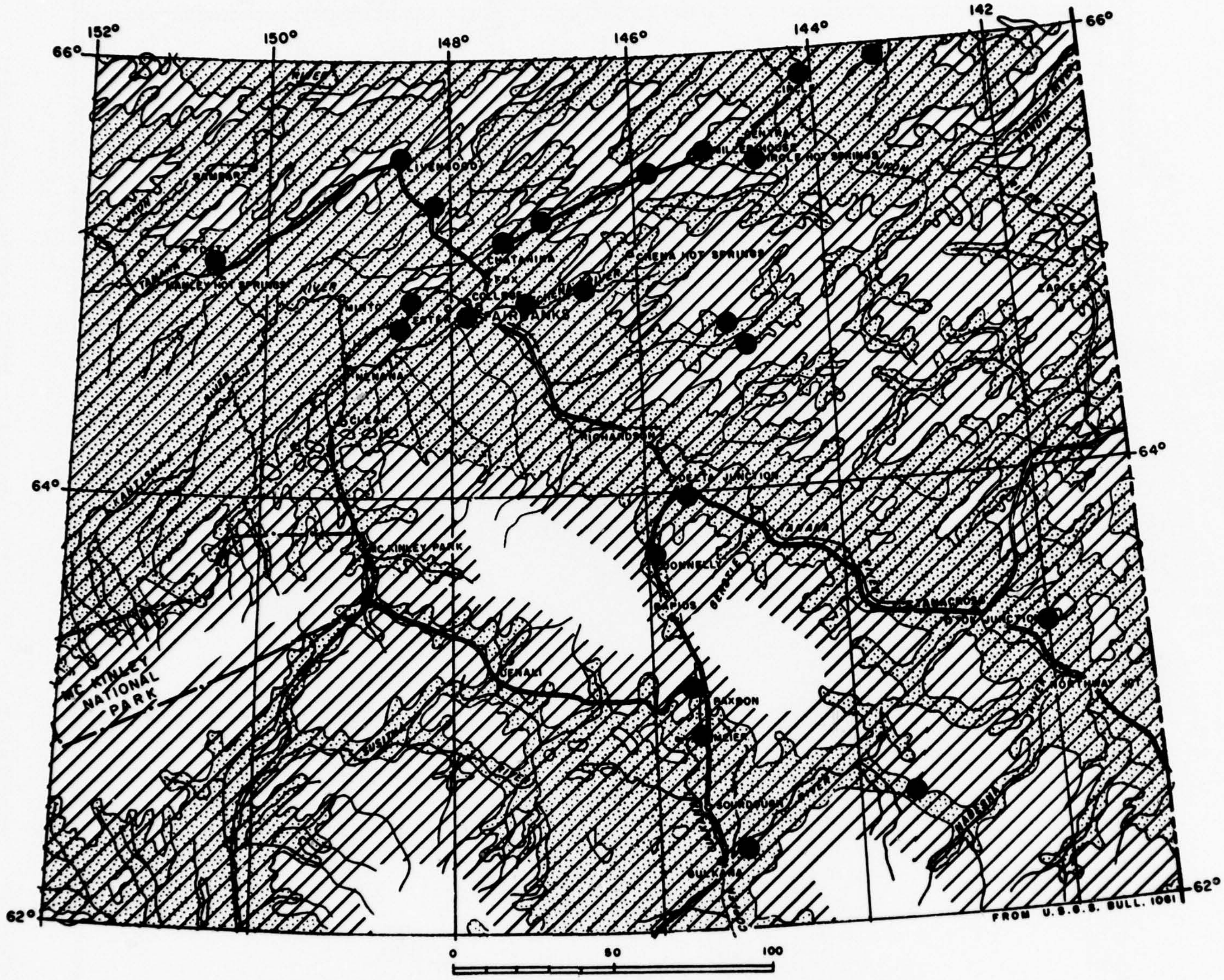
Map 56. Distribution of Microtus pennsylvanicus.



Map 57. Occurrence of <u>Microtus pennsylvanicus</u> in the study region.



Map 58. Distribution of Microtus oeconomus in North America and Eurasia.



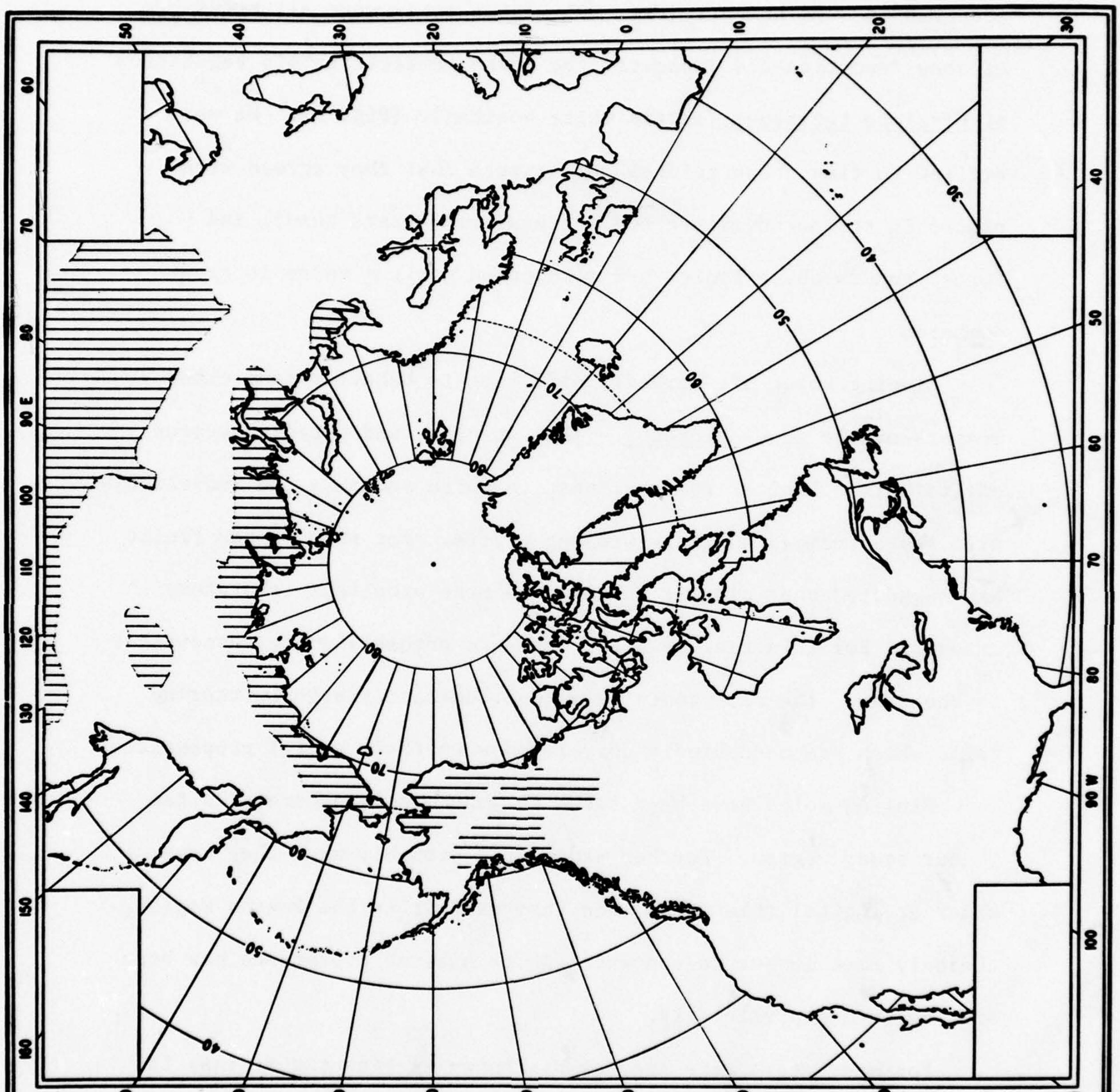
Map 59. Occurrence of Microtus oeconomus in the study region.

restricted sites on the Denali Highway where singing voles occurred in some numbers (Fig. 8). These sites were all areas of snow deposition and supported the characteristic zabois vegetation of Cassiope tetragona (arctic white heather). (Fig. 6). We were excited to find these refuges and to note that they agreed with places in the northwestern and northeastern Alaska tundra and forest-tundra where Pruitt had also noted singing voles in great numbers.

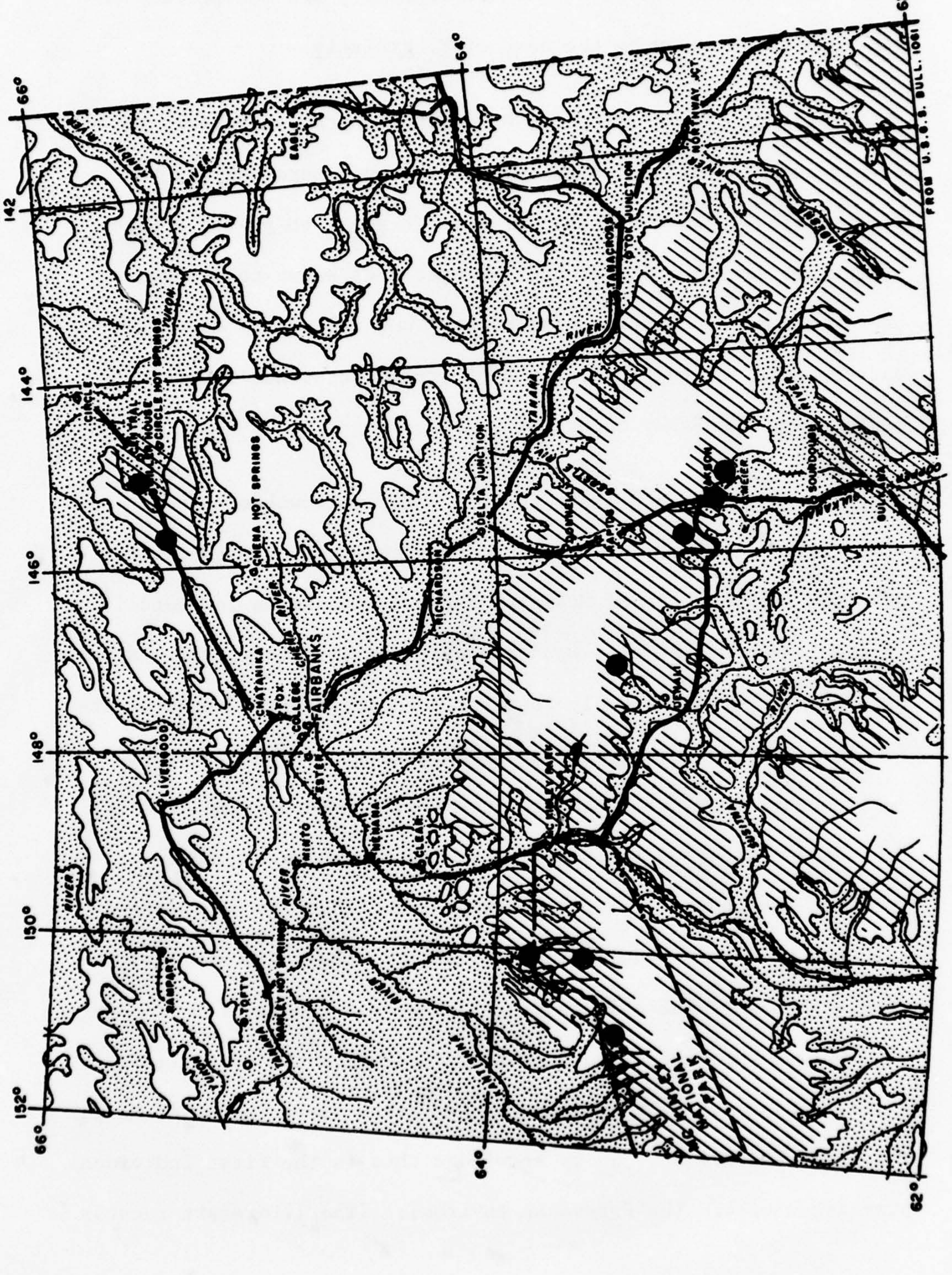
Singing voles are markedly different in behavior from other members of the genus Microtus. This species, undoubtedly because of its marked habitat restrictions, is quite sociable and individuals will share cramped quarters without strife. For this reason Pruitt has suggested that singing voles would make excellent laboratory animals. For this reason, also, they are probably quite susceptible to zoonoses. The name comes from their characteristic twittering calls which are undoubtedly correlated with their social propensities.

Singing voles have been taken in many widely-separated sites in our study region. Further study will probably show they have wider ecological tolerances than they exbibit in the Paxson region, the only site in our region where their habitat preference has been studied even superficially.

For many years this species was known as Microtus miurus; its close relationship to the Old World representative of its subgenus Stenocranius was suspected. Recently Rausch (1964) has obtained sufficient specimens from Eurasia to analyze both the Old and New



Map 60. Distribution of Microtus gregalis in North America and Eurasia.



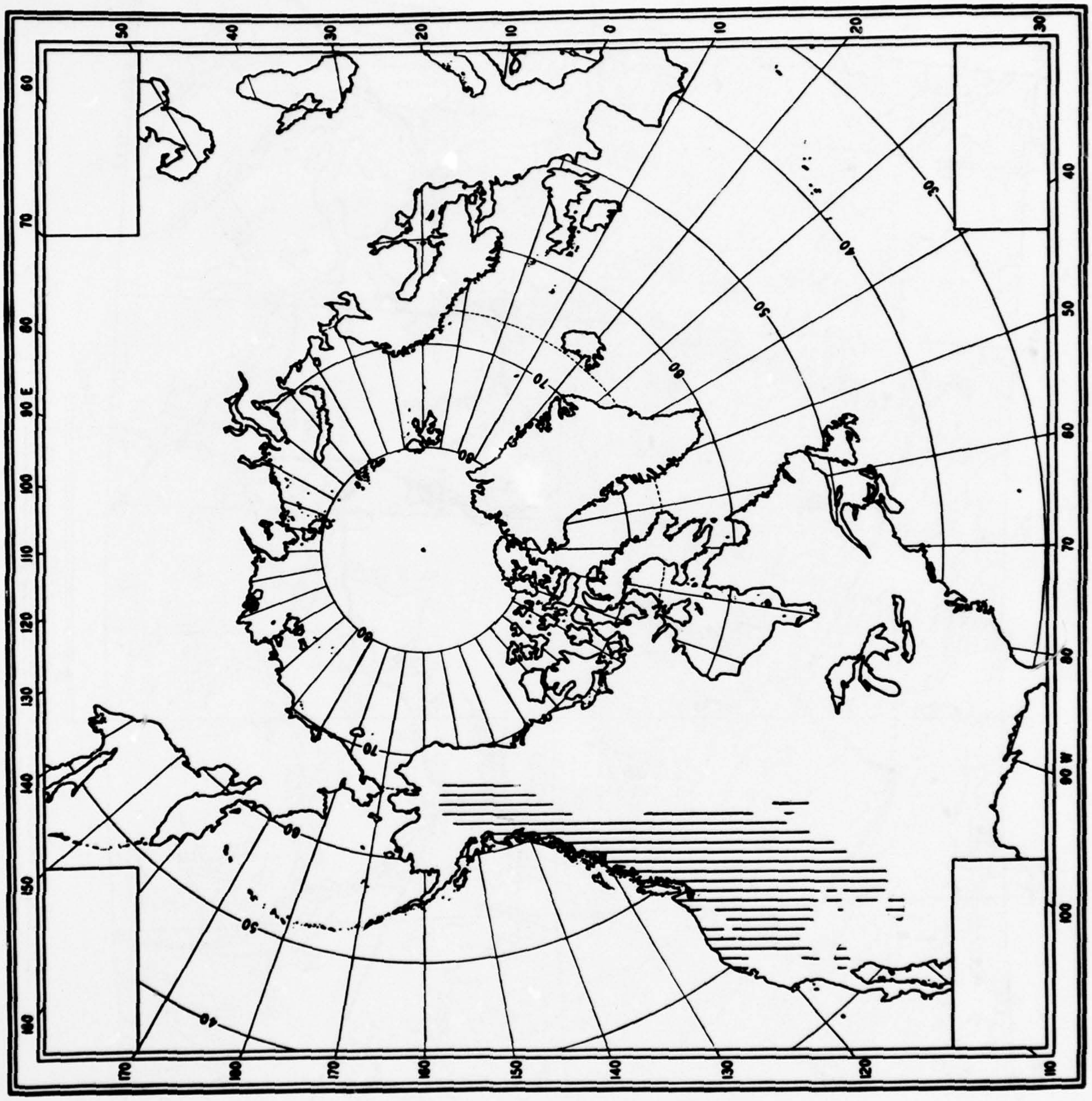
Map 61. Occurrence of Microtus gregalis in the study region.

World populations and has concluded that they are conspecific and should both be known by the name of M. gregalis.

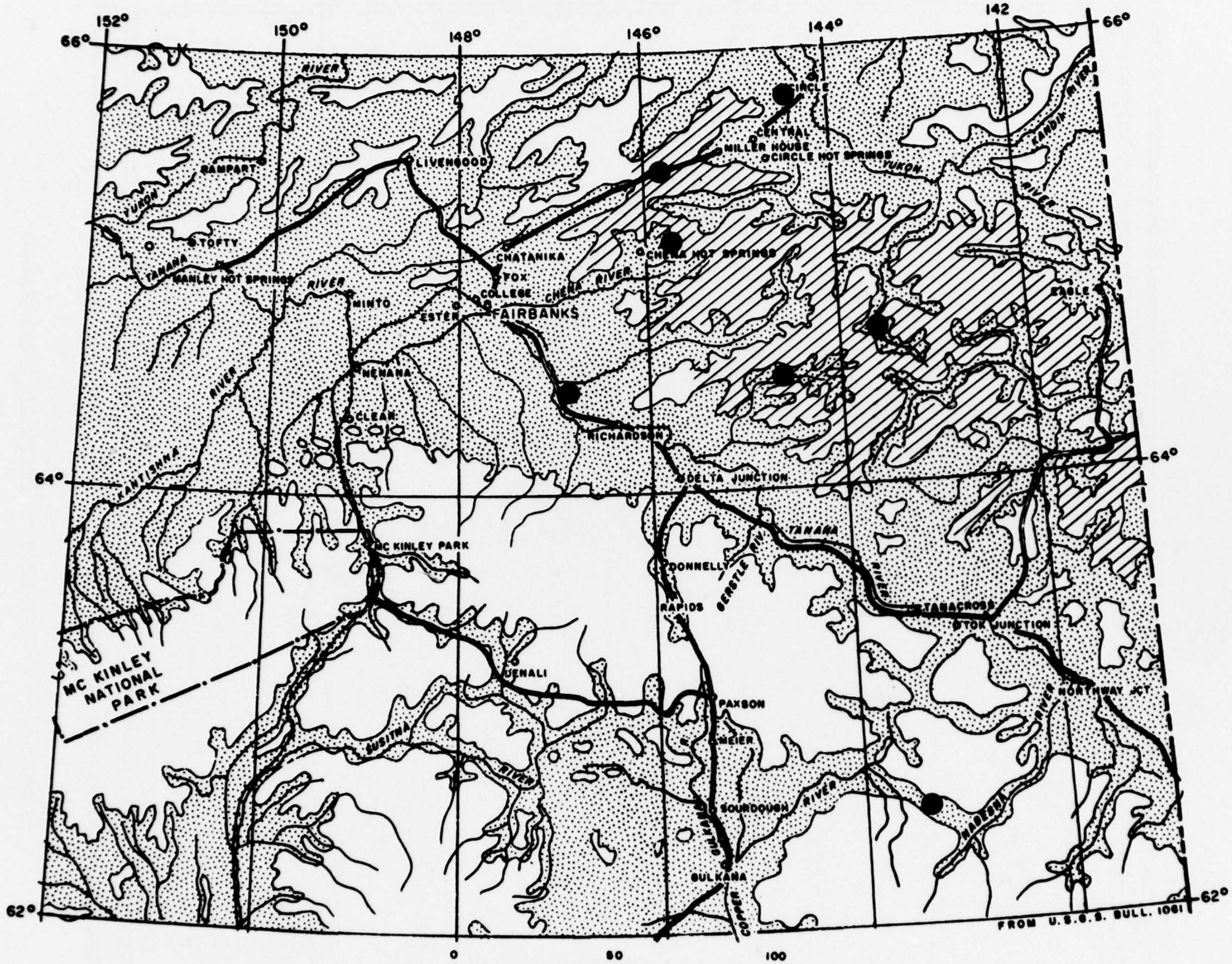
Microtus longicaudus (Maps 62, 63) - The longtailed vole is relatively rare in our study region, being found there only in the Tanana Hills-White Mountains upland. It seems to prefer alpine tundra habitat and most of the few specimens known to me have been taken in association with rocks. Our region is on the extreme edge of its range, which otherwise stretches far to the south along the Rocky Mountains.

Microtus xanthognathus (Maps 64, 65) - The yellowcheeked vole is also rare in collections. In our study region it has been reported from the neighborhood of McKinley Park, Fairbanks, a few localities in the Tanana Hills-White Mountain upland. This large vole is either colonial or markedly restricted in its habitat requirements, for most records refer to large numbers being present within a small area. They are also highly variable in population density; "colonies" have been revisited after one or two years and during this interval have completely disappeared. There is speculative evidence that this species intergrades into the quite similar M. chrotorrhinus of the eastern taiga and forest-tundra of North America.

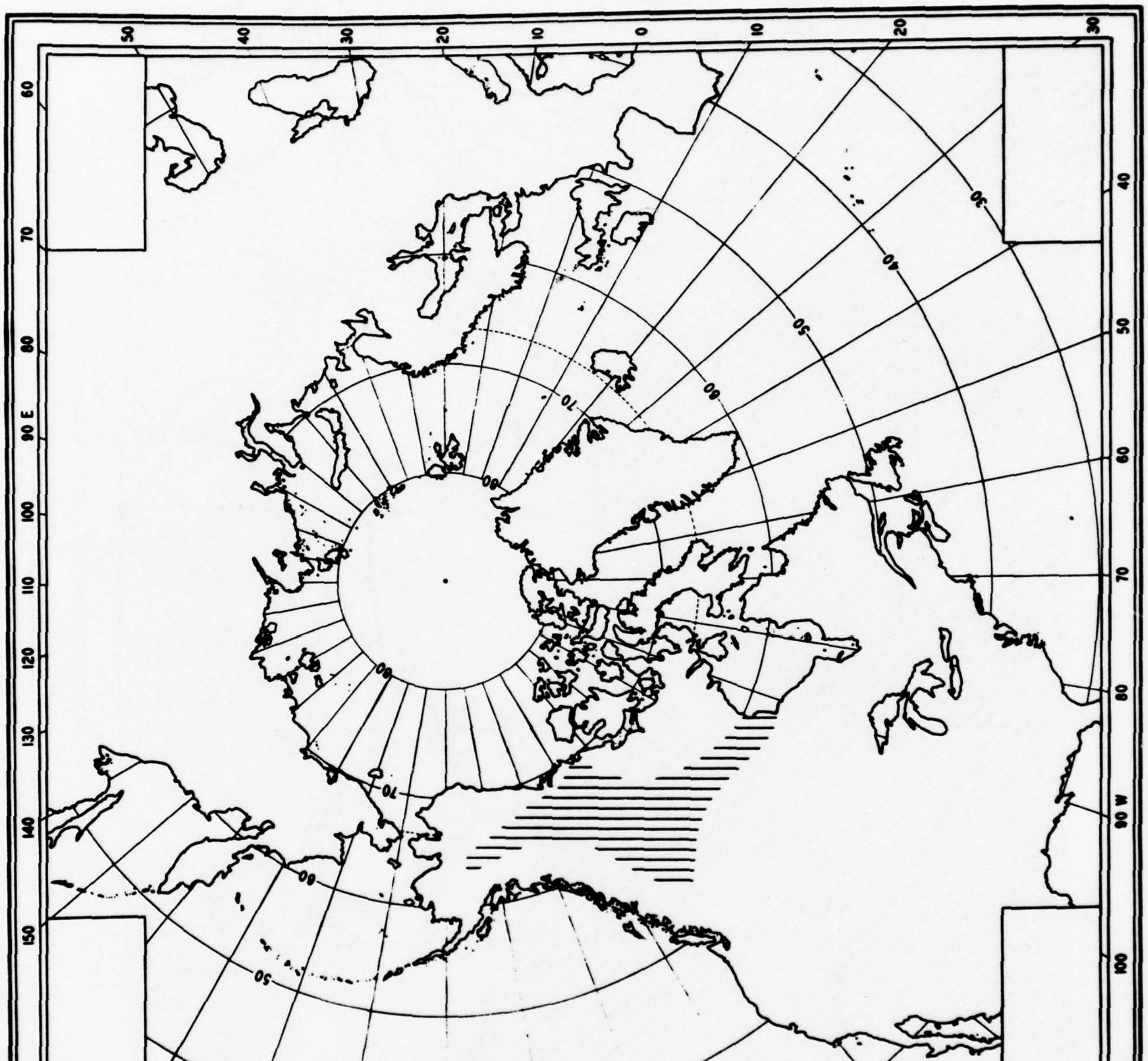
One of the biggest surprises of the summer 1964 was finding a live individual M. xanthognathus wandering about inside of Hangar 1 at Fort Wainwright. To my knowledge this is the first individual ever taken within the Fairbanks environs. (The literature records



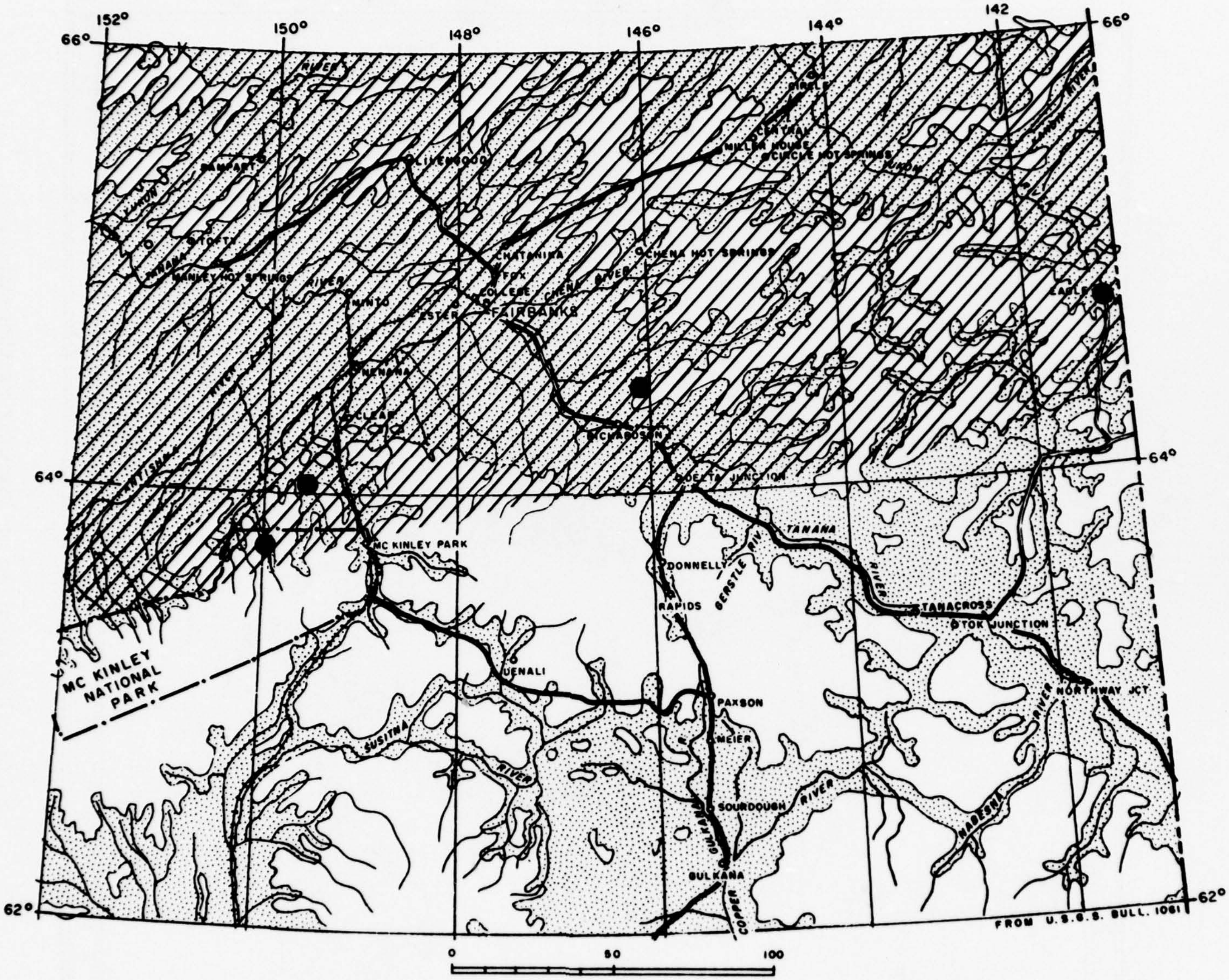
Map 62. Distribution of Microtus longicaudus.



Map 63. Occurrence of Microtus longicaudus in the study region.



Map 64. Distribution of Microtus xanthognathus.

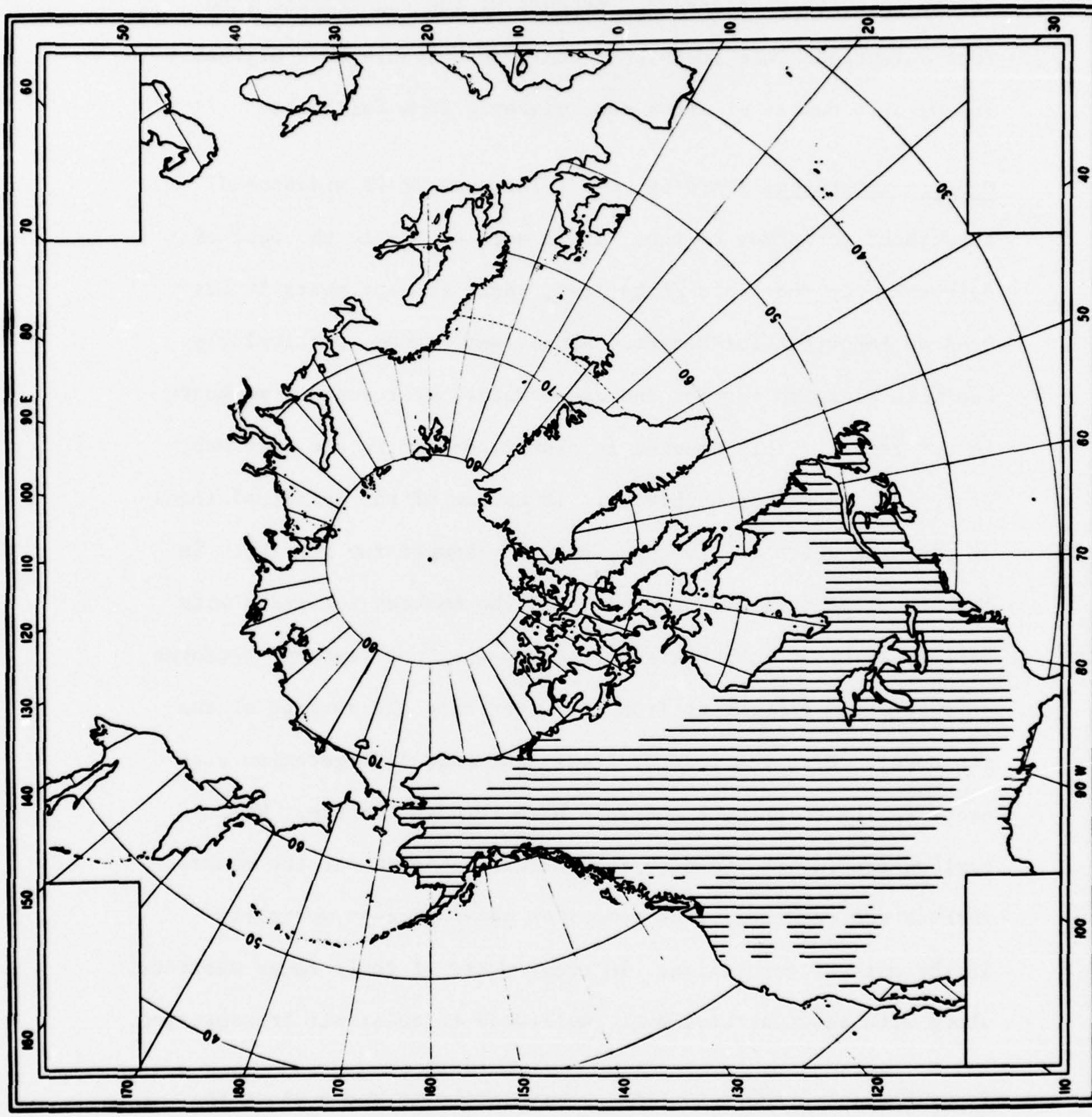


Map 65. Occurrence of Microtus xanthognathus in the study region.

giving "near Fairbanks" are old and could mean a locality anywhere in the interior of Alaska.). Because of the air traffic into Fort Wainwright this individual could conceivable have orginated in any of a number of sites some distance from Fairbanks.

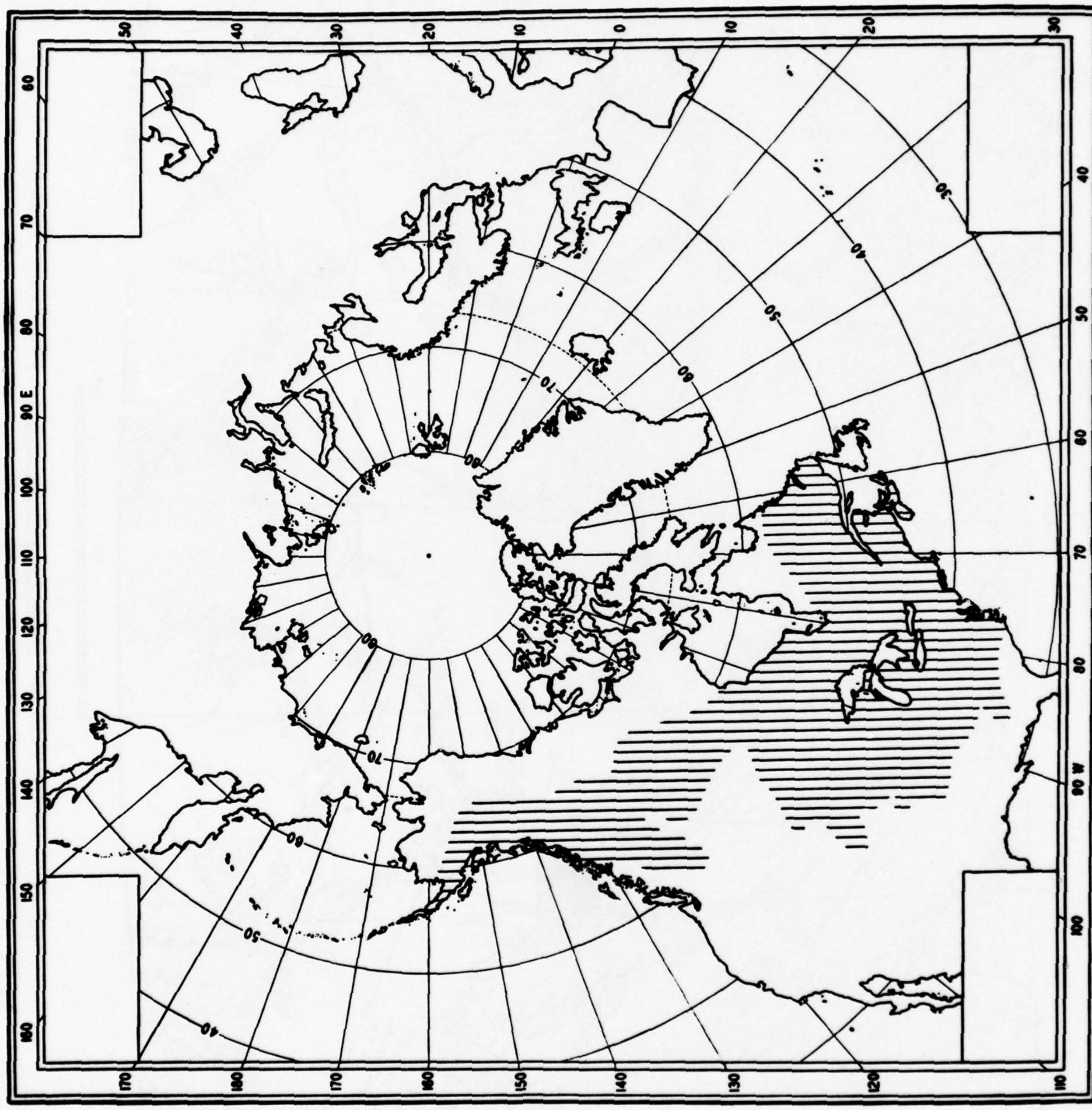
Ondatra zibethicus (Maps 66, 67) - The muskrat is widespread throughout our study region. It is more common to the west of Fairbanks, in the Minto Flats area, where in many years it has been an important fur-bearer. Almost any stream, particularly one with sluggish current and clear water, will support muskrats in our region. This species is also important in the food web, since it is a common herbivore. It is one of the principal foods of the mink which is, in turn, actively sought for its fur. In certain areas (e.g. - Paxson Lake) the muskrat interacts with caribou at times. Muskrats form "push-ups," or feeding platforms of vegetation brought up from the water onto the surface of the ice cover. Here the muskrat feeds; the mass of vegetation also protects its escape and entrance hole through the ice. When caribou are in the vicinity they actively search out the muskrat pushups and eat them, thus sometimes causing great mortality in the muskrat population. In other parts of their range muskrats, along with beavers, have been implicated in tularemia transmission.

Zapus hudsonius (Maps 68, 69) - Very little is known about the jumping mouse in our study region. It seems that our region is on the very northwestern edge of its range. It appears restricted

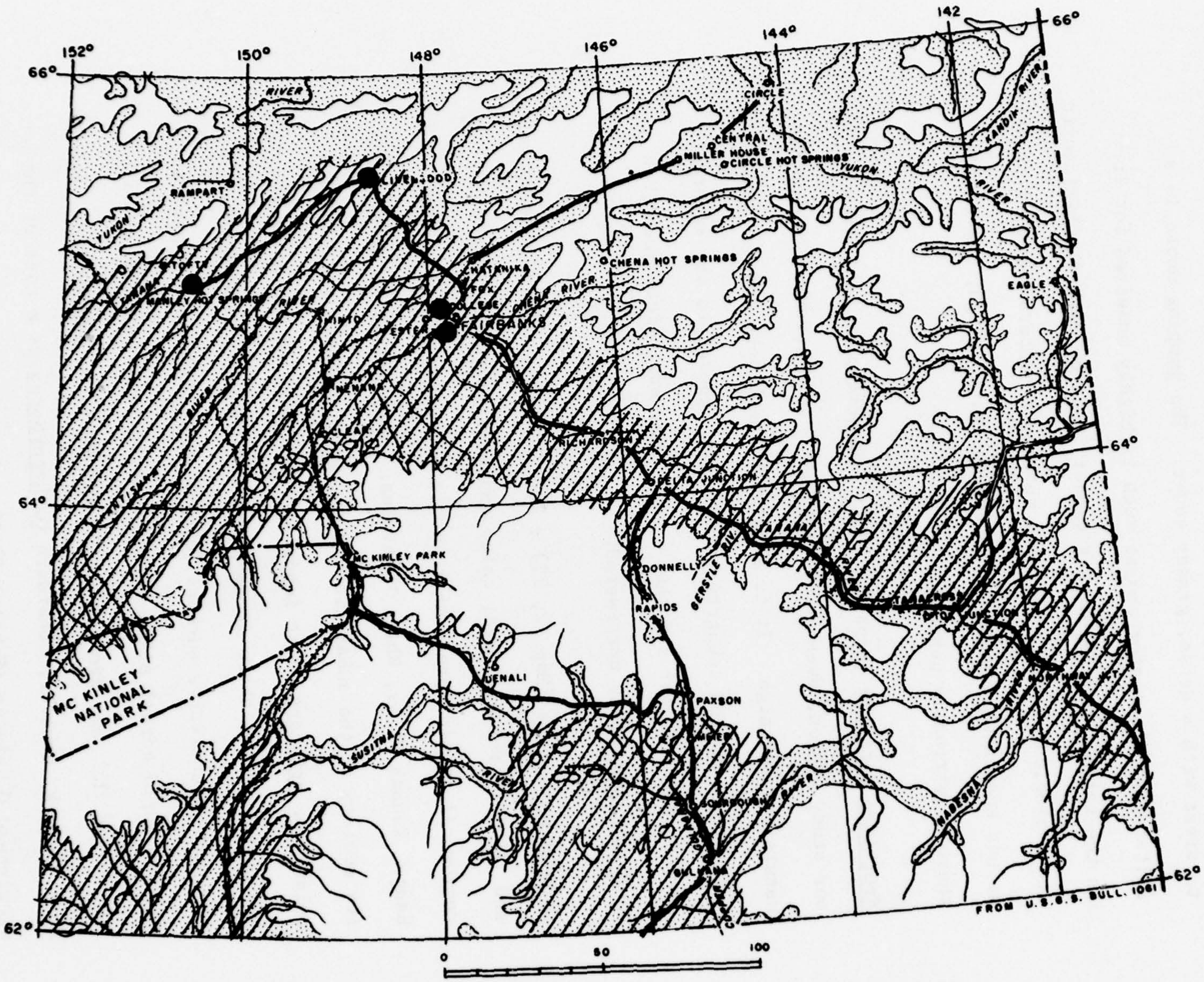


Map 66. Distribution of <u>Ondatra zibethicus</u>.

Map 67. Occurrence of Ondatra zibethicus in the study region.



Map 68. Distribution of Zapus hudsonius.



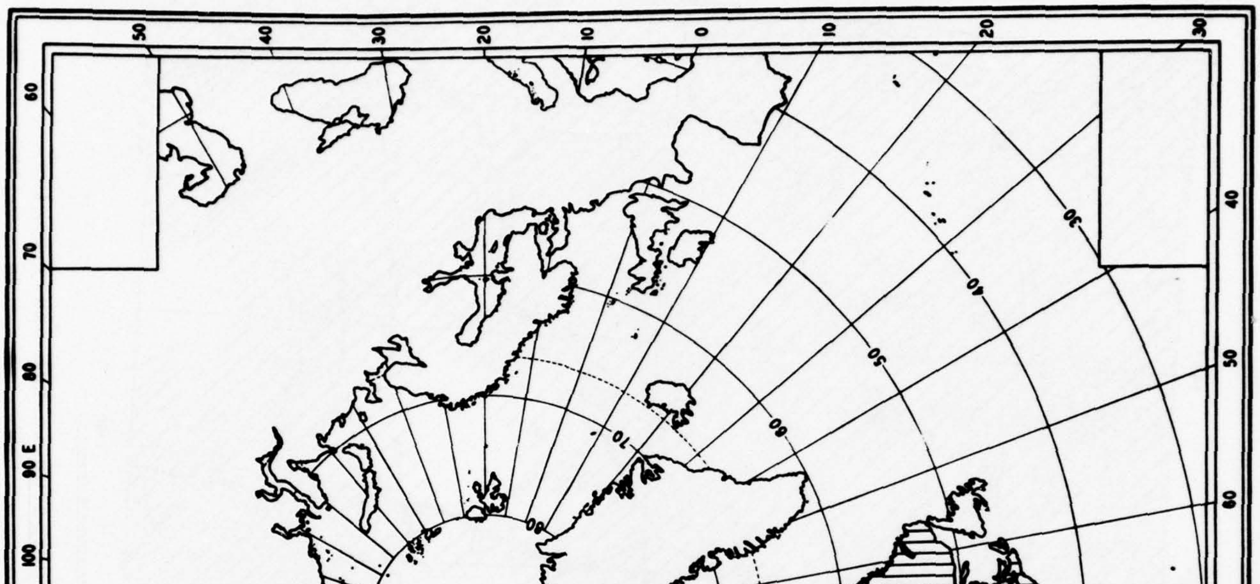
Map 69. Occurrence of <u>Zapus</u> <u>hudsonius</u> in the study region.

to sites with a dense, grassy cover. The jumping mouse is a saltatorial hibernator and as such is highly unsuited for life in the taiga. One would thus expect it to be markedly limited in its ecological requirements and sparse in numbers here. I frankly do not know how it survives in the subarctic taiga; its ecology there is virtually unknown.

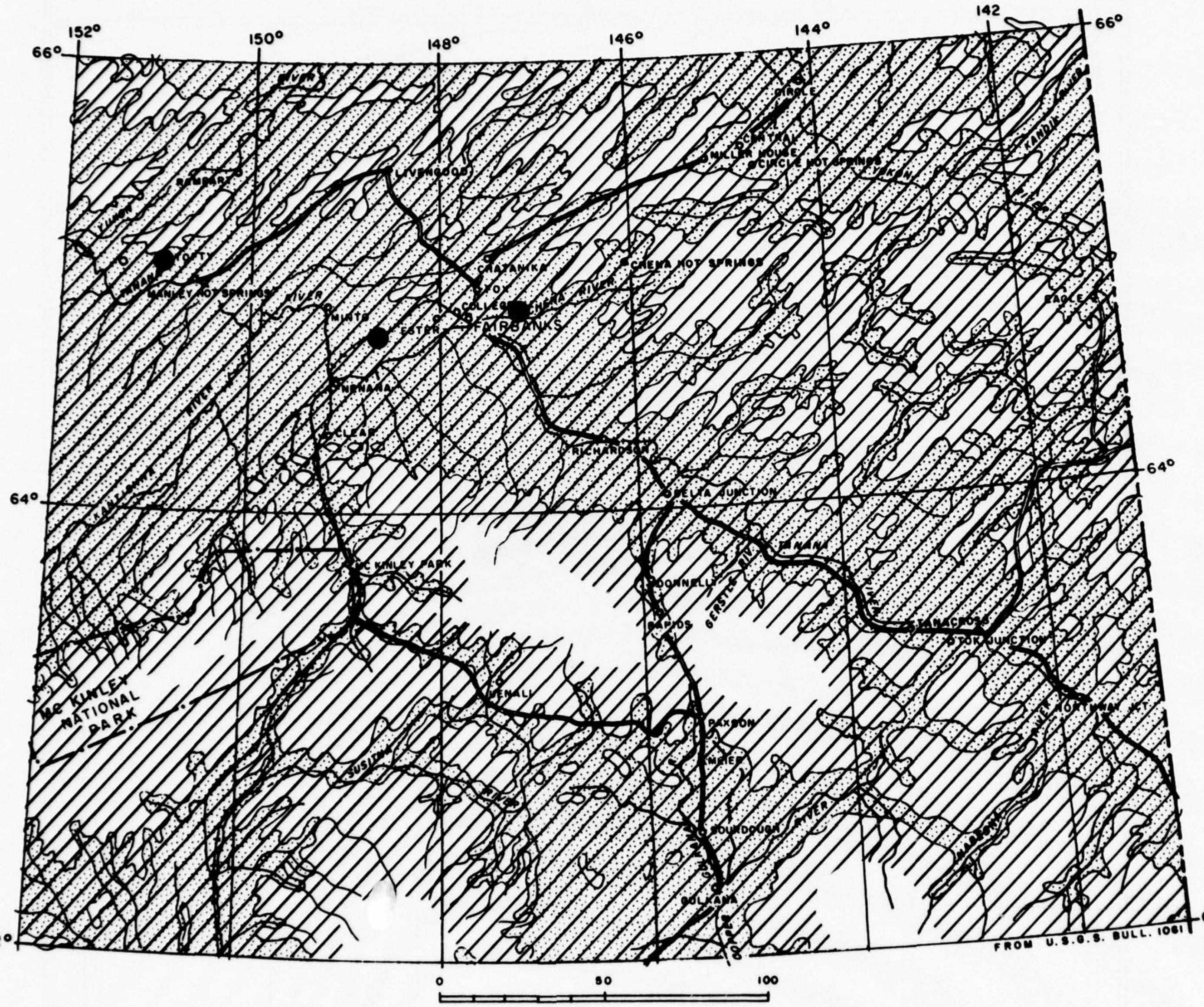
Erethizon dorsatum (Maps 70, 71) - The porcupine is found over all our study region, even above treeline. Its preferred habitat is mature spruce taiga. It is a solitary herbivore and is rarely very common in the subarctic. It lives exposed to the subarctic environment all year and thus poses some ecological questions that are completely unanswered.

Ochotona collaris (Map 72, 73) - The pika is a true alpine mammal and lives on rocky slopes, talus and fresh moraines. In our study regions it is widespread wherever such habitat occurs - Alaska Range, Tanana Hills, White Mountains. Very little is known about its ecology in the subarctic but the more southern and closely related O. princeps is an important herbivore in the Rocky Mountain alpine ecosystem; there it is primarily the prey of weasels.

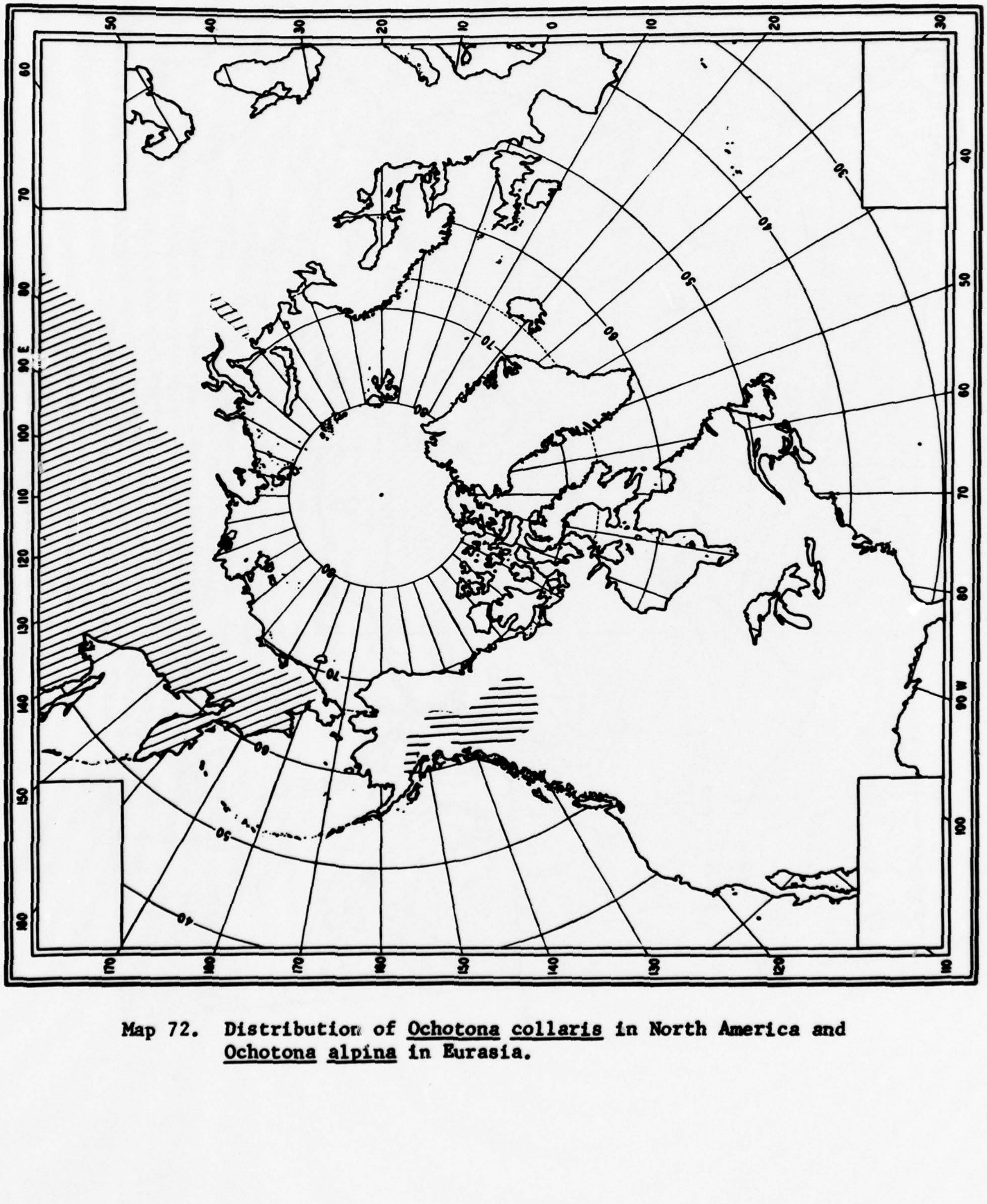
Some speculative authors (e.g. Rausch 1963) have suggested that the New World boreal pikas (not the southern forms) should be considered the same species as the Old World O. hyperborea. Recent Russian work, however, considers O. hyperborea as a race of the more widespread O. alpina (Sokolov 1963). Consequently we have indicated



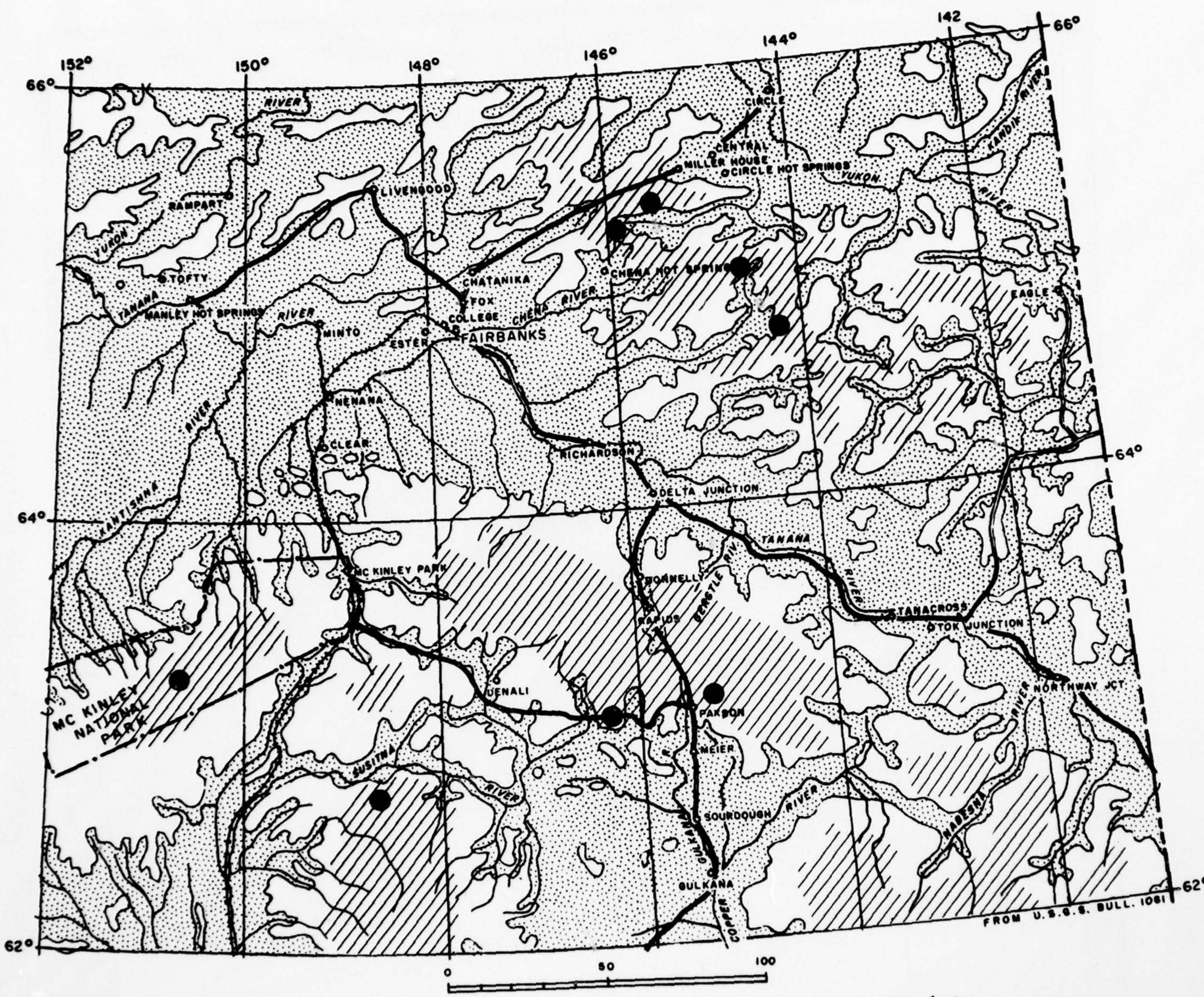
Map 70. Distribution of <u>Erethizon</u> <u>dorsatum</u>.



Map 71. Occurrence of Erethizon dorsatum in the study region.



Map 72. Distribution of Ochotona collaris in North America and Ochotona alpina in Eurasia.



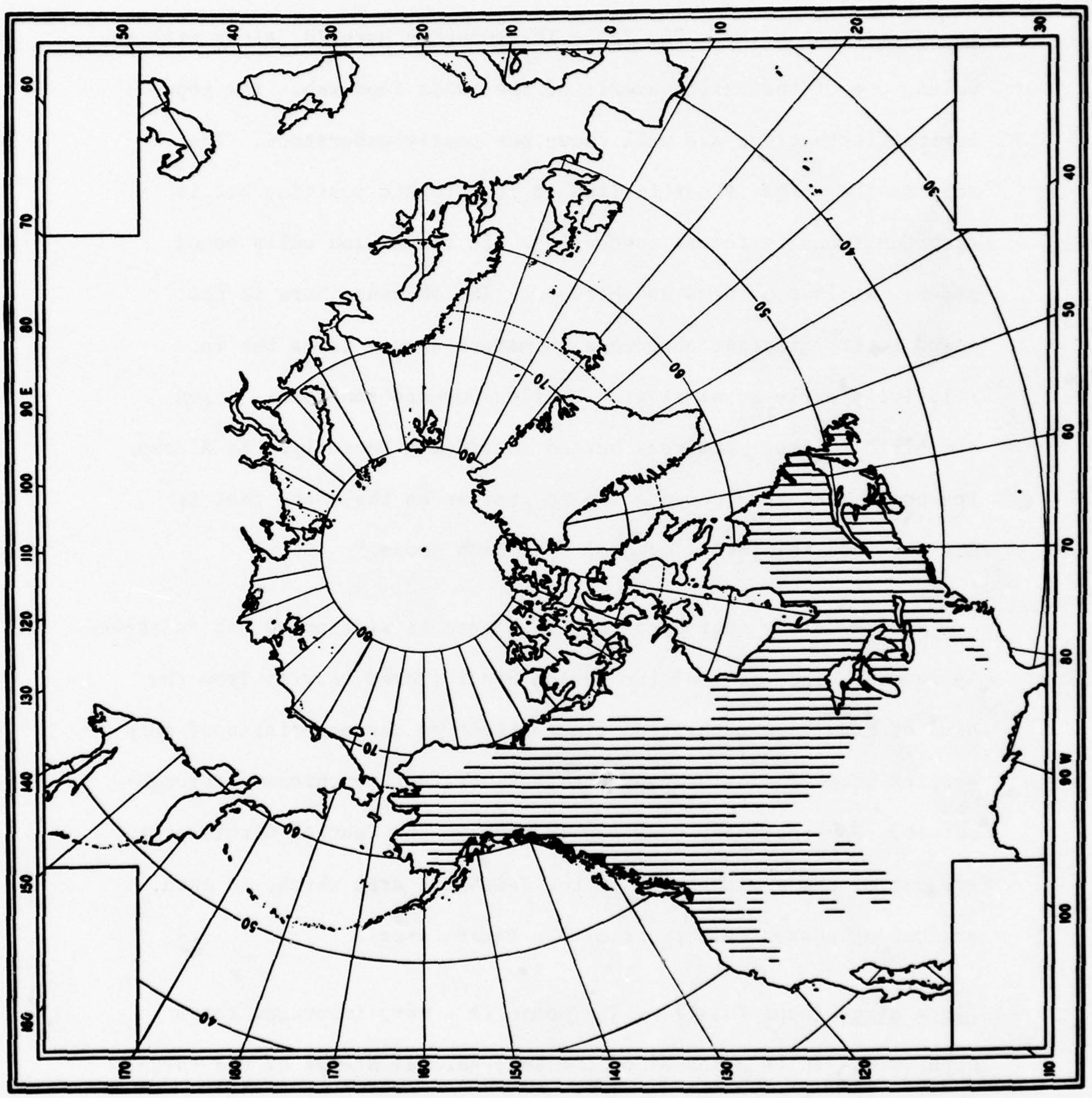
Map 73. Occurrence of Ochotona collaris in the study region.

the ranges of only _O. collaris_ and _O. alpina_.

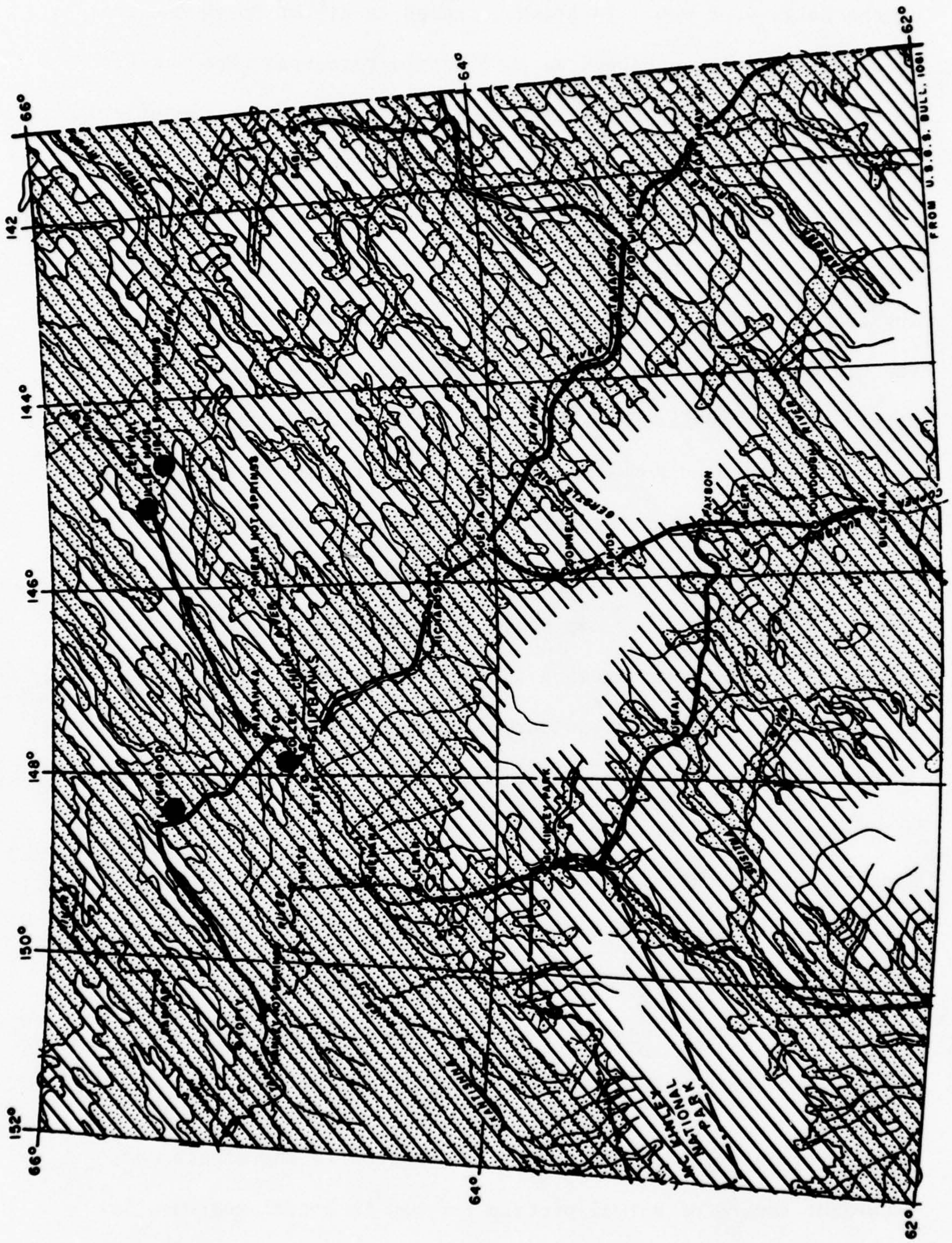
Lepus americanus (Maps 74, 75) - The snowshoe hare is, along with the voles, one of the basic mammals of the taiga food web. Its population fluctuations are well known but poorly understood. Its role in the taiga is not limited to its trophic position but it also functions in forest succession. It prunes and culls young aspens, willows, alders and birches. The showshoe hare is not found in its greatest abundance in mature spruce taiga but in relatively early seral stages - willow-covered sand bars, aspen and birch thickets in areas burned relatively recently. In Alaska its ecological requirements are so similar to the moose that it has received the joking name of "low bush moose."

In our study region the snowshoe hare is widespread and relatively common, since most of the region has suffered heavily from the hand of man. The population fluctuations so characteristic of this species occur in our region, but peaks are not synchronous throughout it. For instance, peak populations in the Central-Circle area are out of phase with those in the Fairbanks area which, in turn, are out of phase with those of the Paxson area.

Alces alces (Maps 76, 77) - The moose is a very important taiga herbivore. It is a mammal of the successional stages of the taiga, not of the mature spruce forest. In our study region it is quite common; to the south in the Susitna and Matanuska valleys it is even more common. They are of considerable economic importance as a source of animal protein, for man as well as other carnivores



Map 74. Distribution of <u>Lepus</u> <u>americanus</u>.

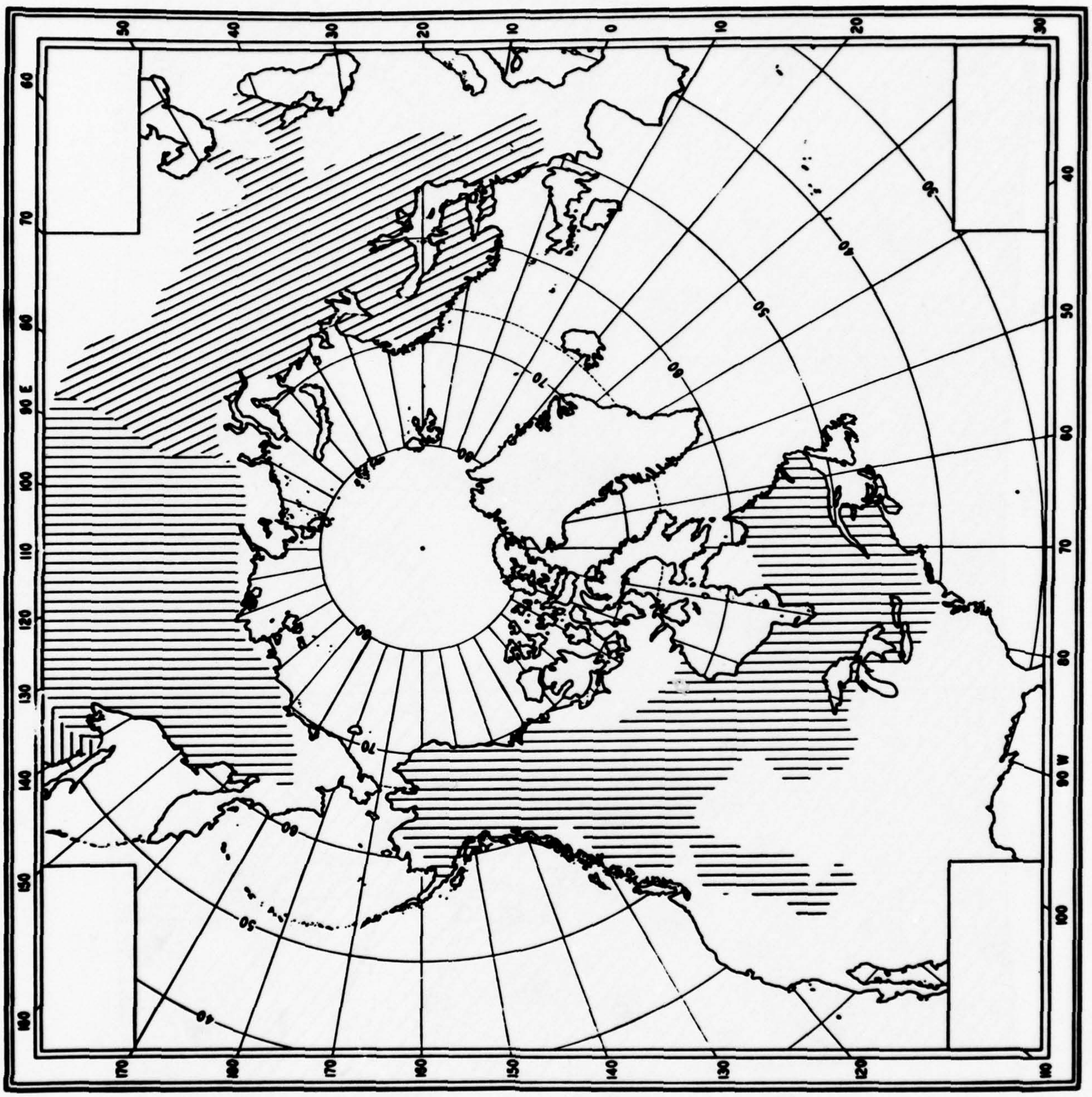


Map 75. Occurrence of Lepus americanus in the study region.

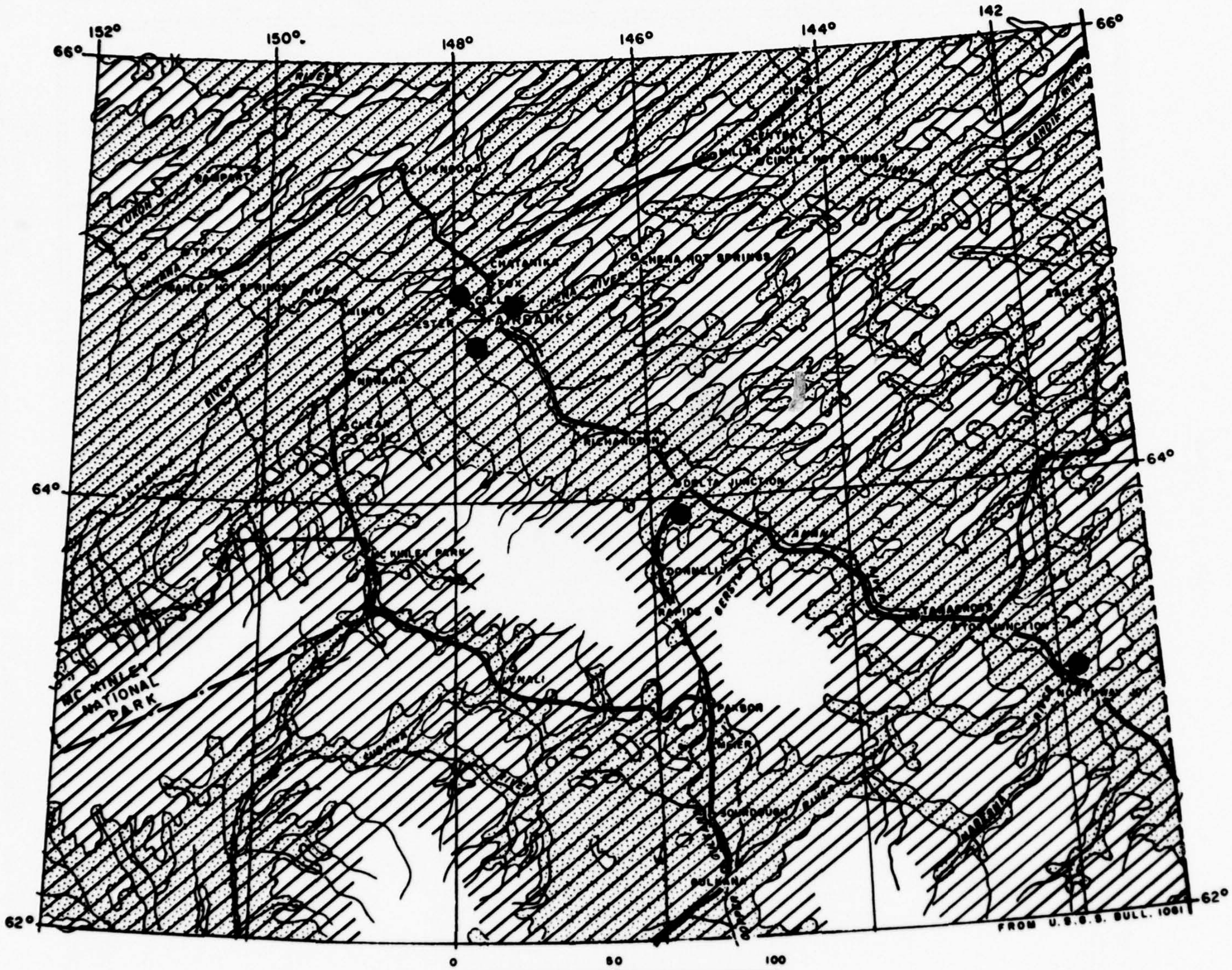
of the taiga food web. In Alaska, indeed in all of North America, they are virtually untapped as an economic resource. The Russian work on domesticating this taiga mammal gives an indication of how rational utilization of taiga resources can be carried on.

The systematic relationships of the moose are still poorly understood. Peterson's (1952) revision used valid data for lumping the Old and New World moose into one species. He separated the Old World forms from the New World forms at the subspecific level. Recent Russian work (Sokolov 1959, 1963; Heptner, Nasimovich and Bannikov 1961) also lump all the moose into one Holarctic species, but they make the intriguing combination of the New World moose with the form in Siberia west to the region of the Yenesei River. Thus our map shows _Alces alces americana_ (in our study region) in North America and eastern Siberia, _Alces alces alces_ in western Siberia and Europe and _Alces alces bedfordiae_ in the Ussuri region. The exact nomenclature is of little significance to us here; what is important is this concept of close kinship between the western Siberian and the New World forms of a very important taiga mammal. In the light of our knowledge of the Bering Platform and its role as a bridge between the Palearctic and Nearctic regions the relationships of moose as outlined in the recent Russian work appear quite logical.

Rangifer tarandus (Maps 78, 79) - The caribou is the single most important source of animal protein for man in boreal regions, but in the Tanana Valley it is not as important as moose. Caribou



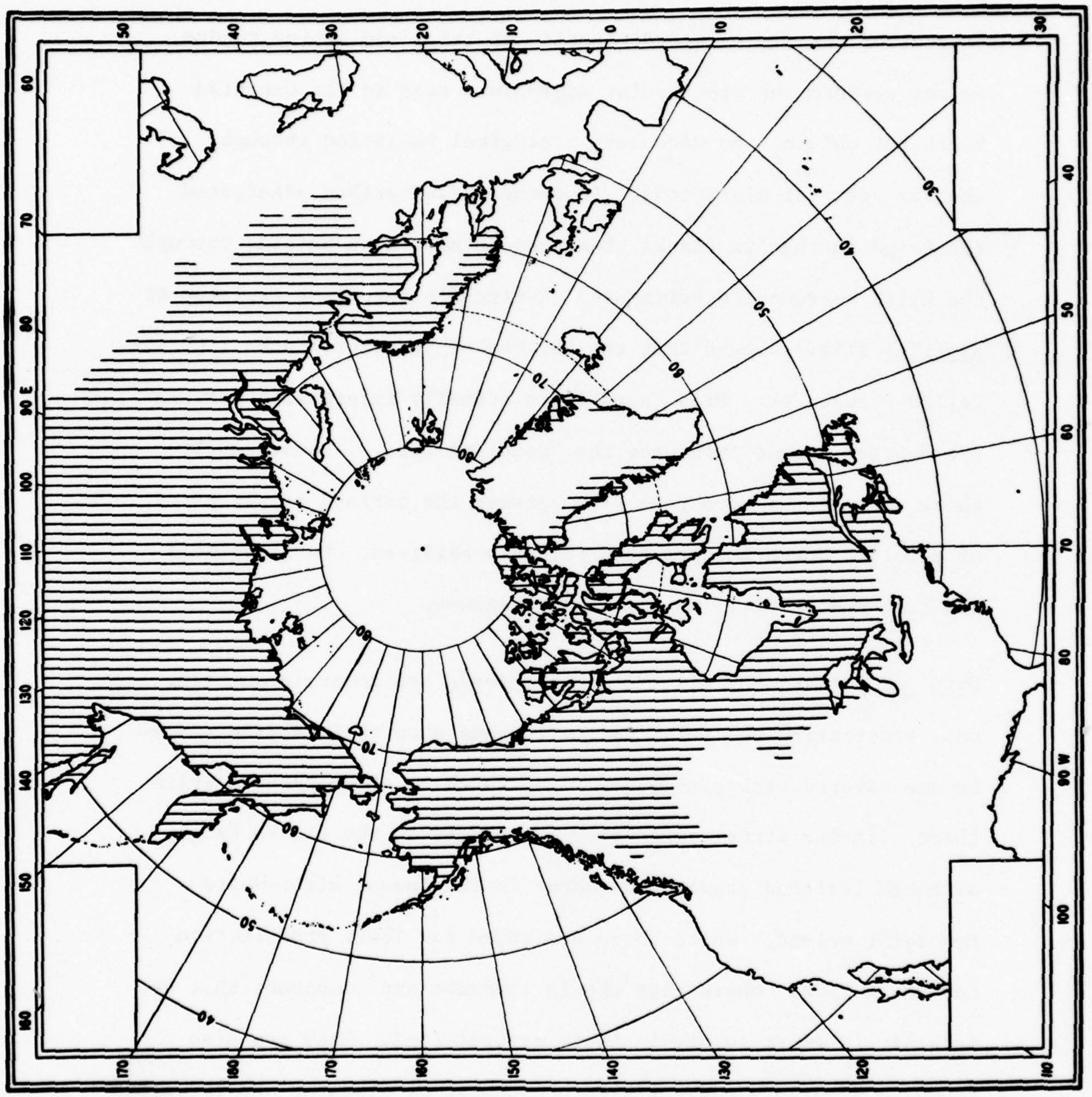
Map 76. Distribution of *Alces alces americana* in North America and eastern Siberia; *Alces alces alces* in western Siberia and and Europe; *Alces alces bedfordiae* in the Ussuri region.



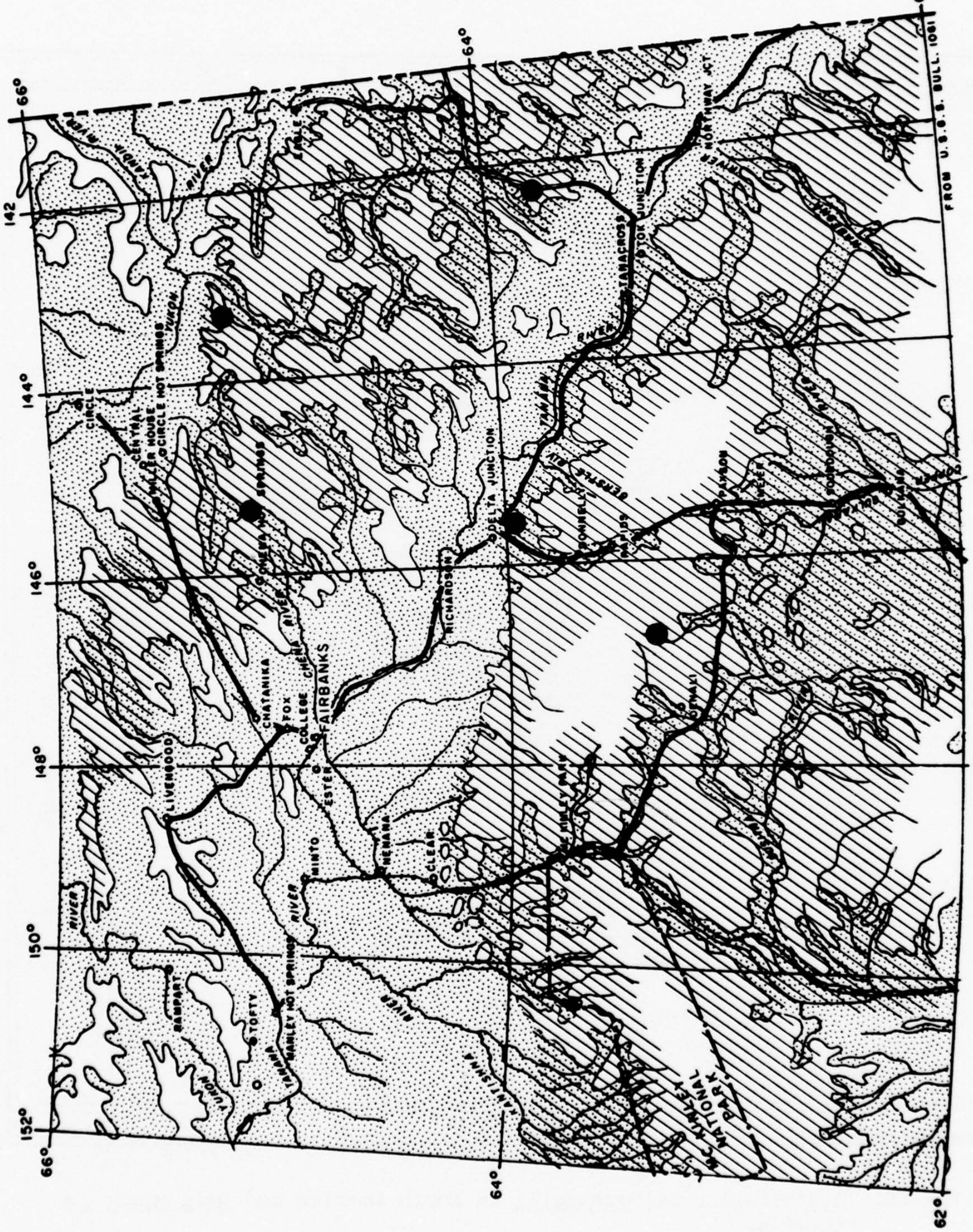
Map 77. Occurrence of <u>Alces alces</u> in the study region.

are essentially tundra animals and over most of their range they only visit the taiga and forest-tundra in winter. Alaska caribou, because of the close interdigitation of taiga and alpine tundra, do not perform the spectacular migrations seen in the Canadian North but obtain the necessary ecological variation through shorter vertical migrations. In former days caribou penetrated the taiga further in Alaska than they do now, even passing through the hills surrounding Fairbanks. Banfield's important revision of *Rangifer* (1961) showed that the caribou of interior Alaska (the so-called Steese-Forty Mile "herd") are actually intergrades between the "barren ground type" and the "woodland type." Consequently there seems to be more gene flow between the caribou of all parts of mainland North America than formerly believed. Our specimens are from hunter kills on the Denali Highway.

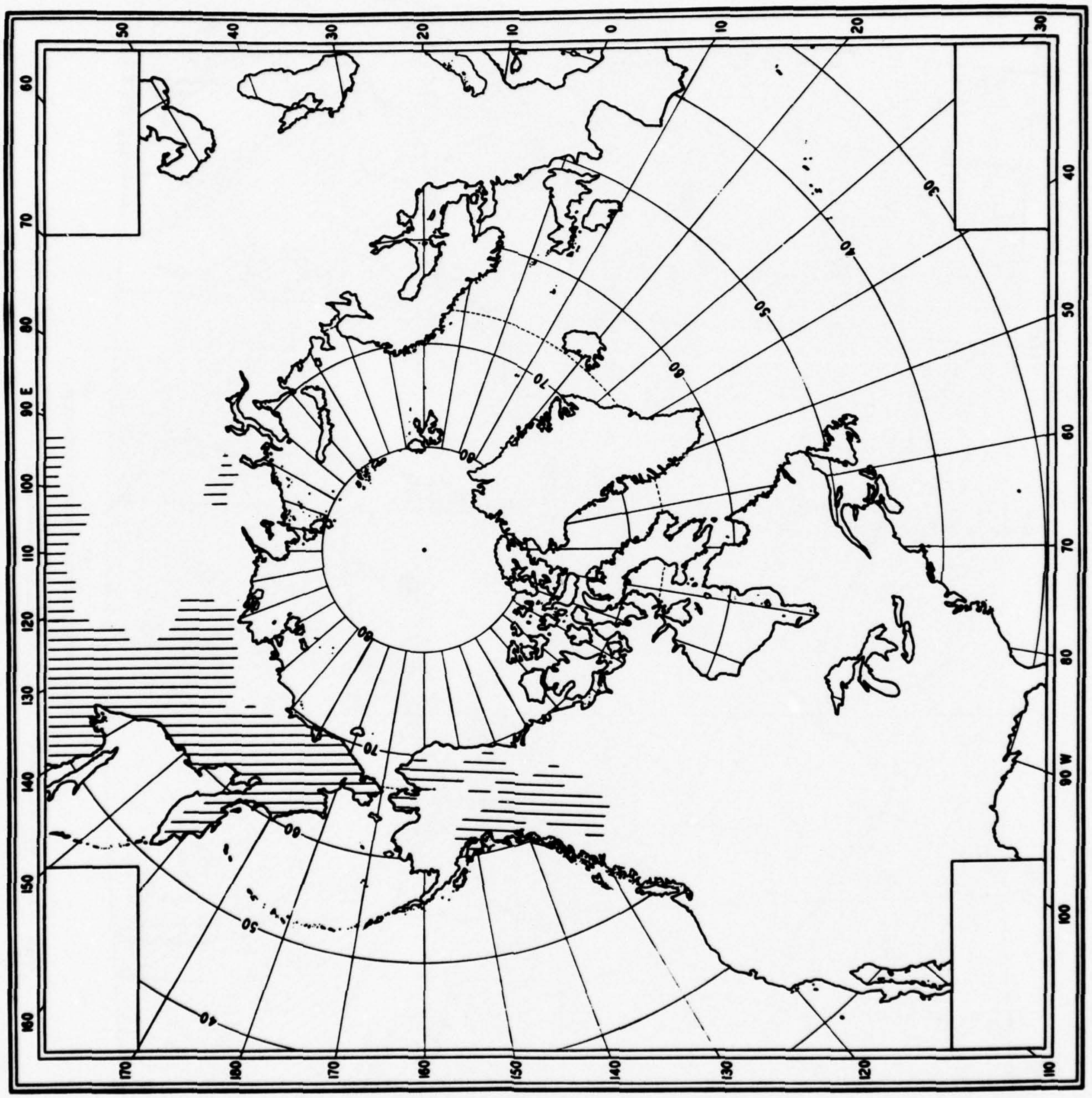
Ovis dalli (Maps 80, 81) - The white sheep are mountain animals, only penetrating the taiga during seasons when their alpine ranges become covered with a snow cover too thick to allow them to graze there. In our study region they are mainly in the Alaska Range, although isolated populations occur in the Tanana Hills-White Mountains upland. White sheep are known for their predeliction for "salt licks" where they obtain elements and compounds that are probably in short supply in their natural food. They are also known to be highly susceptible to a number of diseases and parasites carried by domestic sheep and other ungulates.



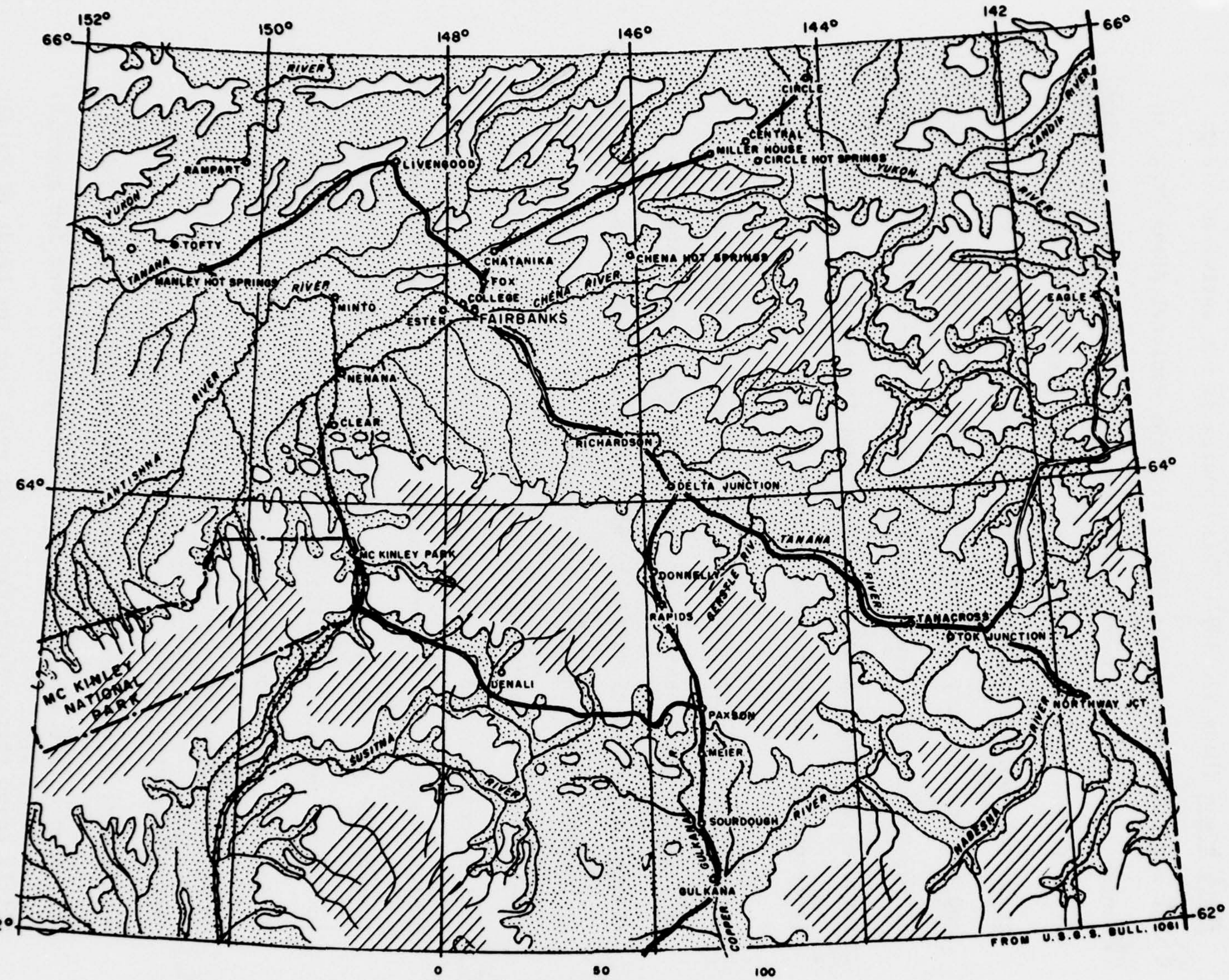
Map 78. Distribution of Rangifer tarandus.



Map 79. Occurrence of Rangifer tarandus in the study region.



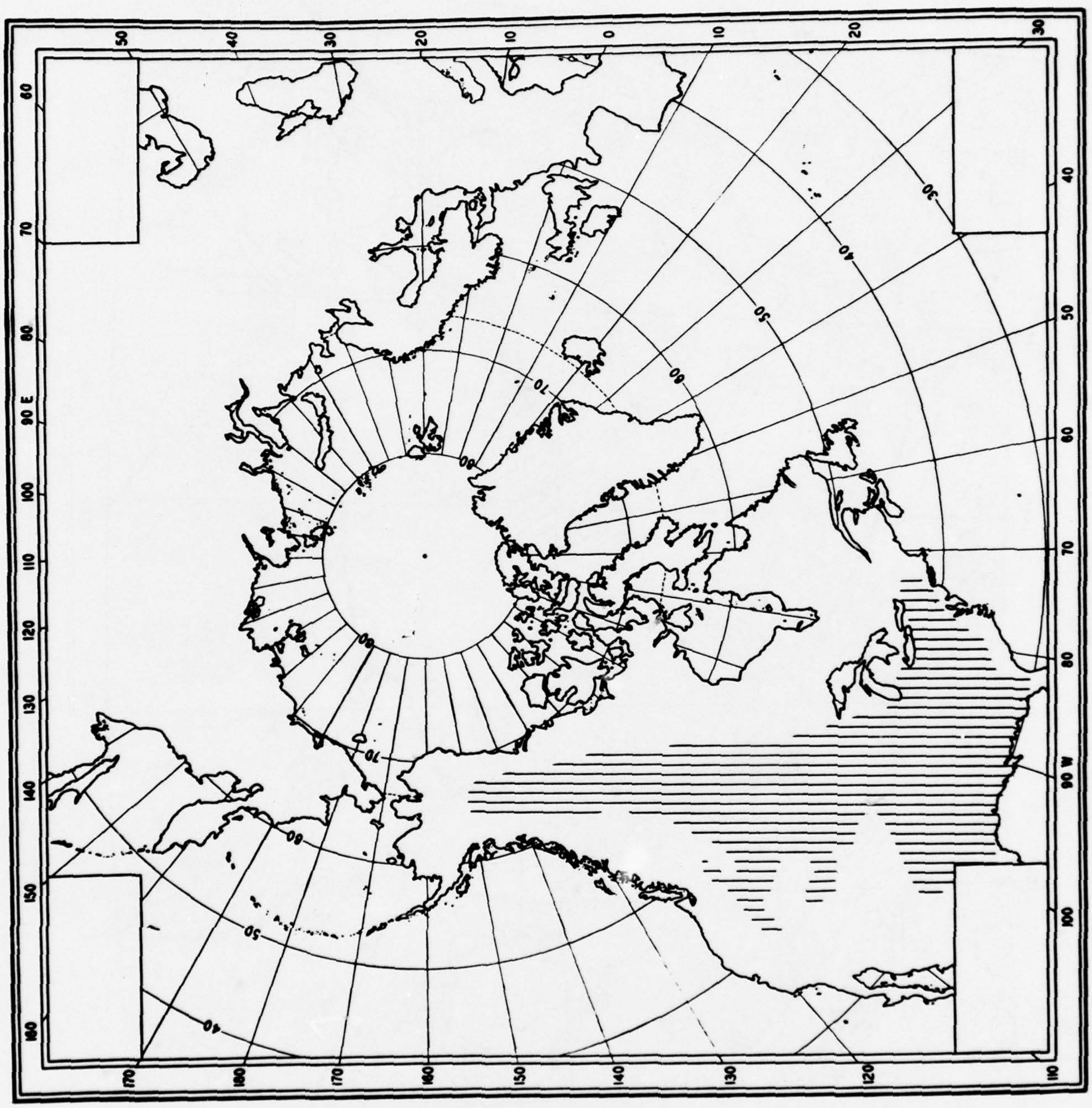
Map 80. Distribution of Ovis dalli in North America and Ovis nivicola in Asia.



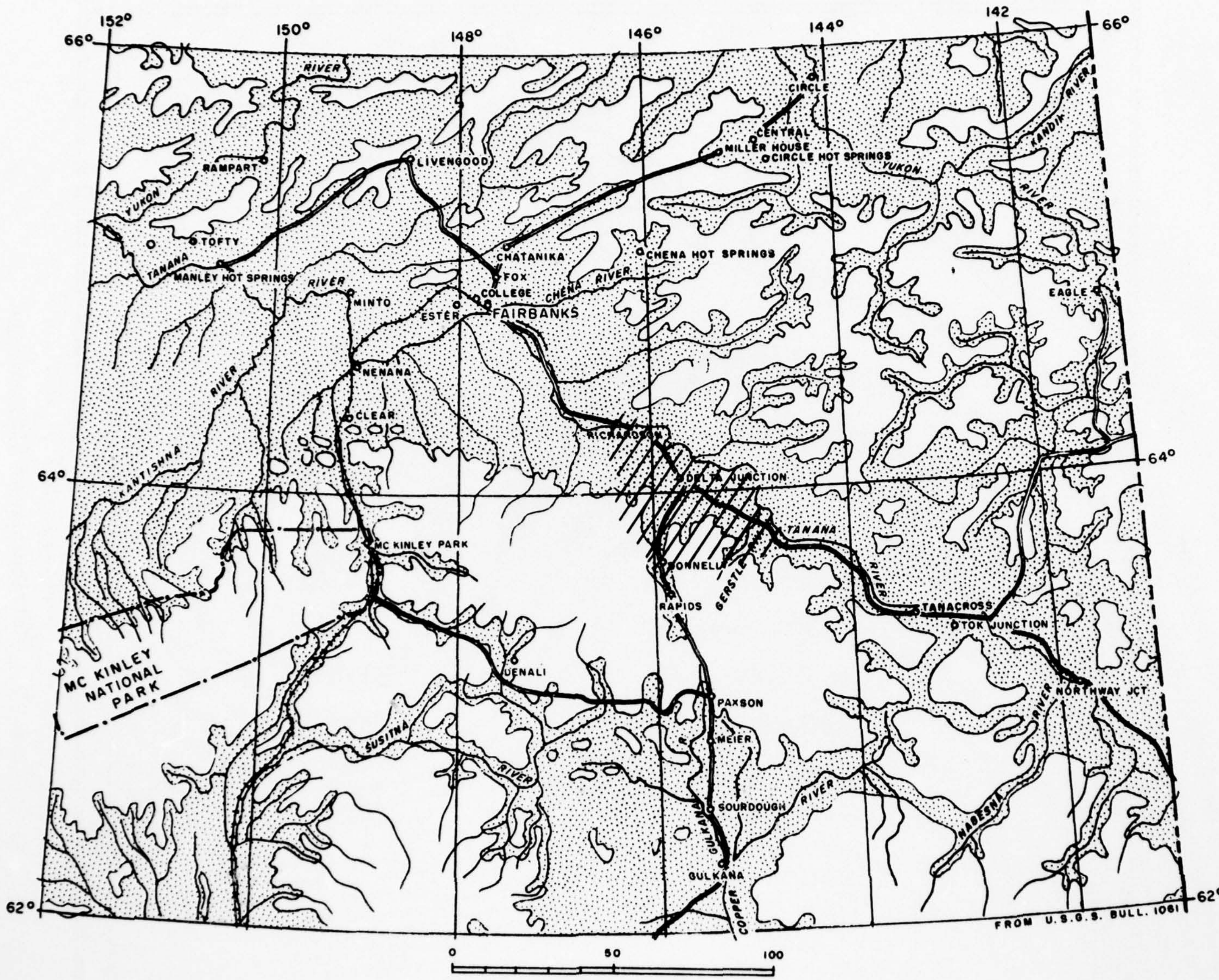
Map 81. Occurrence of <u>Ovis</u> <u>dalli</u> in the study region.

Bison bison (Maps 82, 83) - This species is not native to Alaska but was introduced in the 1920's from the National Bison Range in Montana. Its range in our study region is limited to the vicinity of Delta Junction-Donnelly-Gerstle River, where it frequents open, grassy meadows, fresh burns in the herbaceous stage of recovery, and the open country of forest-tundra and alpine tundra. Residents of the Delta region have experienced many difficulties with bison invading any opening made in the forest; the air-strip at Delta is frequently made hazardous by bison on it.

Bos taurus - The Holstein domestic cow has, in those limited areas of interior Alaska suited for such agriculture, preempted the ecological niches of virtually all the native herbivores. Because of the small size and irregular shape of the agriculturally suitable areas, cows are frequently brought into close contact with the native ecosystem and its mammals. Since the cow is dependent upon a highly modified ecosystem wherein the seres are set far back towards the pioneer stage it is exposed to the violent fluctuations in biomass productivity characteristic of such unstable ecosystems. During such times cows are more liable to be injected into the natural ecosystem because of economic pressures such as the high cost of imported feeds. All of the cows sampled in this study were mature animals and had been raised within the Tanana Valley. According to the owners, no imports had been received for approximately seven years, surprisingly not even from the herds at Palmer.



Map 82. Distribution of Bison bison.



Map 83. Occurrence of Bison bison in the study region.

Table II. Collection of mammals for summer 1964.

	Fairbanks Region						Tanana Hills-White Mts.						Paxson Lake			
	BH	RL	SCR	M21NR	BC	NW	ES	MH	CHS	TH	LR	MHS	HC	DH	TP	Total
S. cinereus	2	5	1								2	5				15
S. arcticus								3					1			4
M. rixosa									1					2		3
M. erminea									1			1				2
L. canadensis										1						1
C. parryi							2		4					6	22	34
T. hudsonicus	6		4	20	53	3		4	14			2				111
L. lemmus							1	1						2		4
C. rutilus	6	10	10	3	7	6		17	21		1	17	7	5		120
M. pennsylvanicus	1		3													4
M. oeconomus	16	60			2		1	13	42		2	71	21			229
M. gregalis							15	1					1	88		105
Z. hudsonius	2										2	4				8
E. dorsatum				1								1				2
O. collaris														15	3	18
L. americanus	1			15				31	1		7	2				60
A. alces														1		1
R. tarandus														14		14
B. taurus	-------173----------															173

BH = Birch Hill
RL = River Lab
SCR = Sheep Creek Road
M21NR = Mile 21, Nenana Road
BC = Bonanza Creek
NW = Nordale Woods
ES = Eagle Summit
MH = Miller House
CHS = Circle Hot Springs
TH = Taylor Highway
LR = Livengood Region
MHS = Manley Hot Springs
HC = Hufman's Camp
DH = Denali Highway
TP = Thompson Pass

BIRDS (Resident)

Canachites canadensis - The spruce grouse is a sedentary permanent resident of mature taiga. It is an herbivore, feeding on buds, twigs and seeds.

Lagopus lagopus - The willow ptarmigan is a semi-permanent resident; that is, it may perform altitudinal migrations from alpine tundra into the taiga or forest-tundra during the winter. It is primarily an herbivore, feeding on buds, twigs, leaves and seeds, but insects and invertebrates are also eaten.

Surnia ulula - The hawk owl is a resident of spruce forest, muskegs and forest-tundra. It is a most un-owl-like owl, being active by day. It is a carnivore, feeding mainly on voles, shrews, insects and small birds.

Perisoreus canadensis - The grey jay or Canada jay is a permanent resident of the spruce forest and all successional stages. It is a scavenger and a carnivore.

Corvus corax - The raven is a permanent resident of all habitats in boreal regions. It is a scavenger, but may also become an active carnivore at times when voles are "high" or when they are especially available as during breakup. Ravens may congregate into large aggregations around food sources and in late winter at the beginning of courtship time.

Acanthis flammea - The mealy redpoll is a very common bird in the taiga regions, nesting and wintering there. The individuals nesting in a region may not be, however, the same individuals which winter there. It is an omnivore, but mainly herbivorous (seeds).

Table III. Collection of resident birds for summer 1964.

	Fairbanks Region						Tanana Hills - White Mts.						Paxson Lake			
	BH	RL	SCR	M21NR	BC	NW	ES	MH	CHS	TH	LR	MHS	HC	DH	TP	Total
C. canadensis				1												1
L. lagopus										2						2
S. ulula				1								1				2
P. canadensis					6			12	1							19
C. corax				1								1				2
A. flammea			1				7		2			3		2		15

BH = Birch Hill
RL = River Lab
SCR = Sheep Creek Road
M21NR = Mile 21, Nenana Road
BC = Bonanza Creek
NW = Nordale Woods
ES = Eagle Summit
MH = Miller House
CHS = Circle Hot Springs
TH = Taylor Highway
LR = Livengood Region
MHS = Manley Hot Springs
HC = Hufman's Camp
DH = Denali Highway
TP = Thompson Pass

BIRDS (Migratory)

Larus canus - The mew gull is relatively common in interior Alaska, nesting in the vicinity of lakes and river bars. It is a carnivore and a scavenger.

Empidonax spp. c.f. trailli - The Empidonax flycatchers are exceedingly difficult to identify and our identifications are not

complete. They are carnivores of the spruce forest and its successional stages, especially in wet areas.

Tachycineta thalassina - The violet-green swallow is found in openings and clearings in the taiga and successional stages. It frequently nests in edificarian habitat with man.

Riparia riparia - The bank swallow is limited, as its name suggests, to cut banks, bluffs and earth exposures having soil of precisely the correct consistency for it to construct burrows. After nesting season is completed this species occasionally joins the following species in large flocks which congregate around edificarian habitat.

Petrochelidon pyrrhonata - The cliff swallow was originally limited in nesting to cliffs, shallow caves and hollow trees. With the invasion of the taiga by man this species has readily invaded edificarian habitat.

Turdus migratorius - The robin is one of the common birds in Alaska, and for the most part nests on the ground especially at the lower montane elevations. Occasional nests are found in the edificarian habitat as well.

Ixoreus naevius - The varied thrush is a species of mature spruce forest. It is a carnivore, feeding on insects and other invertebrates.

Hylocichla guttata - The hermit thrush is not limited to mature spruce forest but is also found in later successional stages. It

is a carnivore, feeding on insects and other invertebrates.

Hylocichla minima - The greycheeked thrush is more common in later successional stages of the taiga than in mature forest. It is also a carnivore, feeding on insects and invertebrates.

Hylocichla ustulata - The olive backed thrush is a species of dense, wet taiga. It is a carnivore, feeding on insects and other invertebrates.

Anthus spinoletta - The water pipit is a tundra bird that seldom enters the lowland taiga. It is a carnivore, feeding on insects and other invertebrates.

Sturnus vulgaris - The starling is an omnivore, an introduced species from Eurasia. Our single record (a partially-mummified carcass) from Manley Hot Springs is a range extension of several hundred miles from the last known outpost of the species.

Seiurus noveboracensis - The northern water thrush is a species of wet, tangled habitats. It is a carnivore, feeding on insects and other invertebrates.

Passerculus sandwichensis - The savannah sparrow is a species of clearings, fields and brushy areas. It is an herbivore.

Junco hyemalis - The slate-colored junco is a species of the edge of forest, in late successional stages. It is an herbivore.

Junco oreganus - Our identification of this specimen is not final; it is many miles outside the known range of the species.

Spizella arborea - The tree sparrow is a species of thin taiga or forest-tundra. It is an herbivore.

Zonotrichia leucophrys - The whitecrowned sparrow is a very common species in the taiga and tundra, nesting on the ground. It is an herbivore.

Passerella iliaca - The fox sparrow is a species of late successional stages. It is an herbivore.

Melospiza lincolnii - Lincoln's sparrow is a species of later successional stages and wet areas. It is an herbivore.

Calcarius lapponicus - The Alaska longspur is a tundra species, found only rarely in the lowland taiga. It is an herbivore.

ARTHROPODS

Until fairly recently, no general studies were published dealing with the arthropods of possible medical importance in Alaska. To be sure, sporadic publications have appeared from time to time outlining the problem for a small localized area in a most superficial way.

SIPHONAPTERA: Jellison and Kohls (1939) listed 17 species of fleas and their hosts. Hubbard (1960) presented a short paper based on a "Packet" of fleas presented to him by Murray Johnson. Some

Table IV. Collection of migratory birds for summer 1964.

	Fairbanks Region						Tanana Hills - White Mts.						Paxson Lake			
	BH	RL	SCR	M21NR	BC	NW	ES	MH	CHS	TH	LR	MHS	HC	DH	TP	Total
L. canus									1							1
E. trailli			3	1		2						1				7
T. thalassina												7				7
R. riparia		36										2				38
P. pyrrhonata		1										2				3
T. migratorius				1				2								3
I. naevius				1	1			2								4
H. guttata												1				1
H. minima								3				2				5
H. ustulata				1		1						16				18
A. spinoletta							11			1						12
S. vulgaris												1				1
S. noveboracensis												3				3
P. sandwichensis									1							1
J. hyemalis			1	1	2			3	6							13
S. arborea								2	8							10
Z. leucophrys			8	1		2	2	7	3			18				41
P. iliaca			1						2			3				6
M. lincolnii									3			7				10
C. lapponicus							6							1		7

BH = Birch Hill
RL = River Lab
SCR = Sheep Creek Road
M21NR = Mile 21, Nenana Road
BC = Bonanza Creek
NW = Nordale Woods
ES = Eagle Summit
MH = Miller House
CHS = Circle Hot Springs
TH = Taylor Highway
LR = Livengood Region
MHS = Manley Hot Springs
HC = Hufman's Camp
DH = Denali Highway
TP = Thompson Pass

of the records in this last study are of dubious validity, as the collection data on the slides frequently do not agree with that presented in publication. In 1963 a paper by Holland dealing with the faunal affinities of Alaska Siphonaptera and an annotated list of species appeared. Holland listed 46 species, an interesting comparison with that of Jellison and Kohls. Hopla (1964) submitted an extensive report to the Arctic Aeromedical Laboratory summarizing 10 years of observations on Alaskan Siphonaptera. Certain parts of this report are condensed and included in subsequent pages.

ACARINA: Very little data have been published concerning the parasitic acarina of Alaska. For that matter, the mesostigmatid mites are essentially unknown and the Ixodoidea have never received any sort of a comprehensive study. Hopla (1959) reported observations on the biology of Haemaphysalis leporis-palustris. Inasmuch as these data, plus other information that has been accumulated over the years, have never been formally published, the salient observations are summarized in some of the following pages.

The other ectoparasites such as Mallophaga and Anoplura are only known by a few individual references, none of which are extensive enough to be worth the listing at this time. Considerable data need to be accumulated and analyzed before these groups of ectoparasites will be understood.

DIPTERA: Most of the important publications dealing with the family Culicidae were those of Frohney (see Appendix B) dealing

with the biology of numerous species of mosquitoes in southeastern Alaska. Sommerman (1953) published on the identification of Alaskan black fly larvae, Stone (1952) on the adult Simuliidae of Alaska, and Sommerman, Sailer, and Esselbaugh (1955) on the biology of the Alaskan blackflies. Jenkins (1952) published most of what has appeared on the Heleidae (Ceratopogonidae). Gjulin, et al. (1961) published their monograph on Alaskan mosquitoes which contributed considerably to the knowledge of the mosquito fauna. Hopla (1964) submitted an extensive report to the Arctic Aeromedical Laboratory on the feeding habits of the arctic and sub-arctic mosquitoes; part of these data are summarized in the following pages.

A summary of the salient information concerning the feeding habits, biology, and host associations of the Siphonaptera, *Acarina*, and Culicidae will follow in that order.

Siphonaptera

Many concepts have been published which dealt with the population density of a particular species of mammal. One of the most popular is termed "trap night" which simply indicates the results of one trap for a 24 hour period. If one sets 300 traps during this period, then 300 trap nights would be reported in this particular setting. This procedure may be correct when one is simply interested in the population density of mammals, but does not lend itself readily to such a study as ours, when one is interested in obtaining tissues for microbiological assay work and collecting the ectoparasites of

the animals. Throughout our operation this past summer we worked as much as possible with live traps. Appropriate size cloth bags were available in which to place the trap, once the specimen was found within, and return it to camp. Upon reaching the field laboratory, the animal was removed with as little trauma as possible, placed in a numbered paper bag and then lightly anesthetized as mentioned earlier. Our traps were checked at as close to 4 hour intervals as was feasible, thus one trap may have had as many as six animals taken during a 24-hour period, which does not allow for expressing trap nights by standard means.

Each species of flea varies in the persistance with which it remains with the dead host, or even, for that matter, a live one. Attempts to get the live animal out of the trap causes some agitation on the part of the animal, and certain species of fleas will depart during this process. Ideally, a trap is needed which will anesthetize the mammal and place it in a bag instantaneously. For example, we found that <u>Peromyscopsylla</u> <u>o</u>. <u>longiloba</u> (Jordan 1939), would leave the host very readily. On the other hand, <u>Malaraeus</u> <u>p</u>. <u>dissimilis</u> (Jordan 1938) would remain with the host for a comparatively long period of time even though the host might be dead. This was not the case with <u>Catallagia</u> <u>d</u>. <u>fulleri</u> Holland, 1951. Two specimens of <u>Amphipsylla</u> <u>m</u>. <u>ewingi</u> Fox, 1940, were secured by locating them after they had jumped from the host. Had it not been for the fact that we were working on a smooth-topped table, and close enough to recapture these fleas immediately, they would have been lost. The

abrupt departure of the latter species from the host leads me to believe that this is one of the reasons why it has been so uncommon in collections.

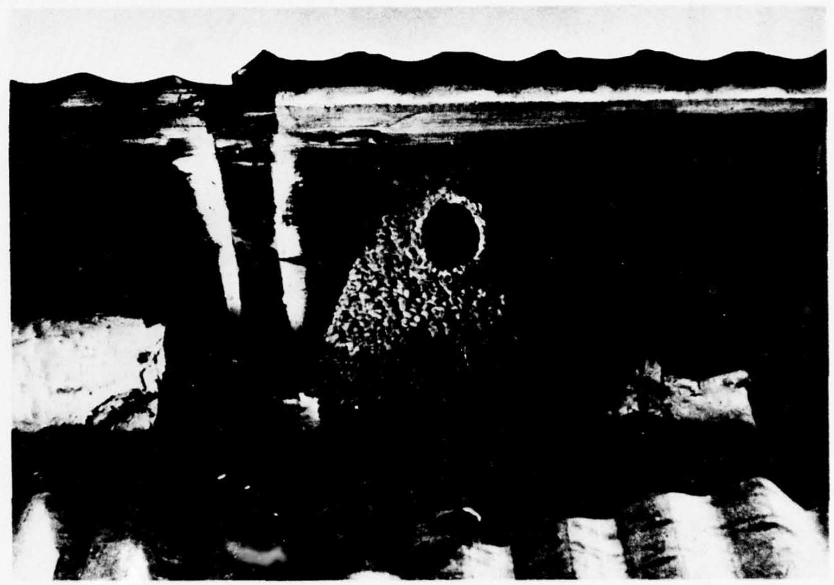
Each mammal was placed in a paper bag of appropriate size, the bag folded from the top and stapled. A field number was written on each bag as well as the time of day (Fig. 11). After each animal had been placed in a paper bag, the series of the same species taken in the same habitat at the same time was then enclosed in a plastic bag. The field number consists of four paired digits, such as 01250864. The first pair of digits indicates the collection number for the day, the second pair the day of the month, the third pair the month of the year and the fourth pair the year of the century. A letter always follows the last pair of digits, "A" indicating animal, "B" indicating burrow, and "N" indicating nest. Meticulous record keeping was maintained in order that the ecto-parasites and tissue would be correlated with the proper animal. We also kept records of those animals which did not have ecto-parasites, our feeling being that it was just as important to know the number of animals that were not infested as it was to know those that were.

While the mammals themselves were a source for obtaining fleas, there are times when the nests revealed a greater number of specimens (Fig. 10). Each nest was given a number as described above, enclosed in a paper bag and this enclosed in a plastic bag

Figure 10. A. Recovery of ectoparasites from mammals. The medium sized rodents, such as this arctic ground squirrel, as well as the microtine rodents, were lightly anesthetized with ether which immobilized the animal long enough for a cardiac puncture. Ectoparasites such as fleas and lice were readily secured after the anesthetization.

B. Nest of the cliff swallow (Petrochelidon pyrrhonata). Such nests frequently contain hundreds of specimens of ectoparasites, particularly fleas.

A



B

Table V. Species distribution of Alaskan fleas, summer 1964. A total of 21 species was collected.

	FE	MHS	CHS	MH	PE	FW	TJ	BC	DL	GL	TP	ES	NDJ	C	NW	RH	FG	Total
Amphalius r. necropinus					1													1
Amphipsylla m. ewingi		1	18	1														20
Catallagia d. fulleri		3	89	5	10	1												108
Ceratophyllus garei		2																2
Ceratophyllus idius		149																149
Ceratophyllus l. tundrensis			4	1														5
Ceratophyllus riparius		45				3												48
Ceratophyllus scopulorum		26					164											190
Chaetopsylla floridensis					21													21
Corrodopsylla c. curvata	2		1		8	1					1							13
Hoplopsyllus g. lynx		2	1	30			66		2									101
Malaraeus p. dissimilis	1	9	26	26	30	36		13	1		1			1	3			147
Megabothris c. gregsoni		22	19	2	1	2		1	2		2		2	4		2		59
Megabothris groenlandicus					5													5
Megabothris quirini	4	26			3	6		9	8					27	3	23		109
Monopsyllus vison	27	13	37	13				37	2		11			2	3	17	11	173
Orchopeas c. durus		7	9	17	14	2		109						5		5		168
Oropsylla alaskensis			10								9							19
Oropsylla idahoensis					3					28	44							75
Peromyscopsylla o. longiloba		67	56	19	5	50									1	1		204
Tarsopsylla o. coloradensis			1								1							2

FE = Fairbanks Environs
MHS = Manley Hot Springs
CHS = Circle Hot Springs
MH = Miller House
PE = Paxson Environs
FW = Ft. Wainwright
TJ = Tok Junction
BC = Bonanza Creek
DL = Dot Lake
GL = Gulkana Lake
TP = Thompson Pass
ES = Eagle Summit
NDJ = North Delta Junction
C = College
NW = Nordale Woods
RH = Richardson Highway
FG = Ft. Greeley

Figure 11. Illustration of field numbering system and method of "bagging" mammals for the recovery of ectoparasites.

and shipped back to the University of Oklahoma, where the nest materials were placed in a modified Berlese funnel. The funnels were scrubbed meticulously after running the nest in order to prevent any cross-contamination from fleas which might happen to cling to a particle of debris near the bottom of the funnel. Table 5 shows the number of fleas taken at each locality, as well as the host from which they were removed. Tables 6 through 15 reveal the host associations of the mammalian fleas, whereas 16 through 25 indicate the number of fleas removed from a particular rodent.

With the data reviewed in the above tables, a discussion of the distribution of Alaskan fleas seems pertinent. Over the past ten years, I have accumulated evidence to account for 52 species of fleas occurring throughout Alaska. In the following presentation I have not included most of the specimens which I know only from one or two collection records, nor have I included representatives of such genera as Dasypsyllus and Mioctenopsylla, which have only been known from sporadic collections in the Bering Sea islands. In other words, my remarks are confined to the species about which I have sufficient data to draw valid conclusions. For the most part, these records concern the interior, or the Tanana Valley, of Alaska.

I have listed the fleas according to the biotic provinces of Dice (1943), and I have attempted to show the fleas that occur in

Table VI. Siphonaptera associated with _Mustela_ _erminea_ in study region, summer 1964.

	Total No. fleas collected	No. positive collections	Ave. Host
Ceratophyllus _l_. _tundrensis_	4	2	2.0
Chaetopsylla _floridensis_	15	1	15.0
Orchopeas _c_. _durus_	4	2	2.0
Oropsylla _alaskensis_	1	1	1.0
Peromyscopsylla _o_. _longiloba_	2	1	1.5

Table VII. Siphonaptera associated with _Mustela_ _rixosa_ in study region, summer 1964.

	Tot. no. fleas collected	No. positive collections	Ave. Host
Amphipsylla _m_. _ewingi_	12	1	12.0
Ceratophyllus _l_. _tundrensis_	1	1	1.0
Corrodopsylla _c_. _curvata_	1	1	1.0
Malaraeus _p_. _dissimilis_	1	1	1.0
Megabothris _c_. _gregsoni_	1	1	1.0
Peromyscopsylla _o_. _longiloba_	1	1	1.0

Table VIII. Siphonaptera associated with _Mustela_ _vison_ in study region, summer 1964.

	Tot. no. fleas collected	No. positive collections	Ave. Host
Chaetopsylla _floridensis_	6	1	6.0
Malaraeus _p_. _dissimilis_	1	1	1.0
Orchopeas _c_. _durus_	13	1	13.0

Table IX. Siphonaptera associated with Lepus americanus in study region, summer 1964.

	Tot. no. fleas coll.	No. pos. coll.	Ave. Host
Hoplopsyllus g. lynx	35	18	1.9
Malaraeus p. dissimilis	2	1	1.5
Monopsyllus vison	2	2	1.0

Table X. Siphonaptera associated with Citellus parryi in study region, summer 1964.

	Tot. no. fleas coll.	No. pos. coll.	Ave. Host
Oropsylla alaskensis*	19	5	3.8
Oropsylla idahoensis**	73	19	3.8

* ex. Citellus p. osgoodi
** Citellus p. plesius

Table XI. Siphonaptera associated with Tamiasciurus hudsonicus in study region, summer 1964.

	Tot. no. fleas coll.	No. pos. coll.	Ave. Host
Monopsyllus vison	161	51	3.2
Megabothris quirini	4	1	4.0
Orchopeas c. durus	148	50	3.0
Tarsopsylla o. coloradensis	2	2	1.0

Table XII. Siphonaptera associated with Ochotona collaris in study region, summer 1964.

	Tot. no. fleas coll.	No. pos. coll.	Ave. Host
Amphalius r. necopinus	1	1	1.0
Malaraeus p. dissimilis	6	3	2.0
Megabothris groenlandicus	5	2	2.5
Oropsylla idahoensis	2	2	1.0

Table XIII. Siphonaptera associated with Microtus gregalis in study region, summer 1964.

	Tot. no. fleas coll.	No. pos. coll.	Ave. Host
Corrodopsylla c. curvata	5	4	1.3
Malaraeus p. dissimilis	5	4	1.3
Megabothris c. gregsoni	4	4	1.0
Megabothris groenlandicus	4	3	1.3
Megabothris quirini	2	1	1.5

Table XIV. Siphonaptera associated with Microtus oeconomus in study region, summer 1964.

	Tot. no. fleas coll.	No. pos. coll.	Ave. Host
Amphipsylla m. ewingi	8	7	1.1
Catallagia d. fulleri	64	21	3.0
Ceratophyllus garei	1	1	1.0
Corrodopsylla c. curvata	2	1	1.5
Malaraeus p. dissimilis	50	35	1.4
Megabothris c. gregsoni	39	32	1.2
Megabothris quirini	21	15	1.4
Monopsyllus vison	3	3	1.0
Orchopeas c. durus	2	2	1.0
Peromyscopsylla o. longiloba	182	77	2.4

Table XV. Siphonaptera associated with Clethrionomys rutilus in study region, summer 1964.

	Tot. no. fleas coll.	No. pos. coll.	Ave. Host
Catallagia d. fulleri	44	24	1.0
Corrodopsylla c. curvata	3	2	1.5
Malaraeus p. dissimilis	88	36	2.4
Megabothris c. gregsoni	13	12	1.1
Megabothris quirini	80	34	2.4
Monopsyllus vison	6	3	2.0
Orchopeas c. durus	1	1	1.0
Peromyscopsylla o. longiloba	14	10	1.4

these provinces as one unit in order that the reader may get an overall impression with less difficulty. It should be kept in mind that those listed for the Hudsonian Biotic Province are identical to the ones occurring in our study region (Tanana Valley).

ESKIMOAN BIOTIC PROVINCE:

Ceratophyllus lunatus tundrensis Holland, Malaraeus penicilliger dissimilis (Jordan), Megabothris calcarifer gregsoni Holland, Megabothris groenlandicus (Wahlgren), Oropsylla alaskensis (Baker).

AMPHI-ESKIMOAN - HUDSONIAN BIOTIC PROVINCES:

Ceratophyllus lunatus tundrensis Holland, Malaraeus penicilliger dissimilis (Jordan), Megabothris calcarifer gregsoni Holland, Megabothris groenlandicus (Wahlgren), Nosopsyllus fasciatus (Bosc), and Oropsylla alaskensis (Baker).

HUDSONIAN BIOTIC PROVINCE:

Hoplopsyllus glacialis lynx (Baker), Corrodopsylla c. curvata (Rothschild), Catallagia dacenkoi fulleri Holland, Epitedia wenmanni (Rothschild), Peromyscopsylla ostsibirica longiloba (Jordan), Amphipsylla marikovskii ewingi I. Fox, Amphipsylla sibirica pollionis (Rothschild), Ceratophyllus arcuegens Holland, Ceratophyllus riparius Jordan and Rothschild, Ceratophyllus idius Jordan and Rothschild, Ceratophyllus scopulorum Holland, Ceratophyllus celsus celsus Jordan, Ceratophyllus garei Rothschild, Ceratophyllus lunatus tundrensis Holland, Malaraeus penicilliger dissimilis (Jordan), Megabothris calcarifer gregsoni Holland, Megabothris groenlandicus (Wahlgren), Megabothris quirini (Rothschild), Monopsyllus vison (Baker), Orchopeas caedens caedens (Jordan), Orchopeas caedens durus (Jordan), Opisodasys pseudarctomys (Baker), Tarsopsylla octodecimdentata coloradensis (Baker), Oropsylla alaskensis (Baker), Oropsylla arctomys (Baker), Chaetopsylla floridensis I. Fox, Chaetopsylla tuberculaticeps ursi (Rothschild).

UPLAND TUNDRA:

Ctenophyllus terribilis (Rothschild), Malaraeus penicilliger dissimilis (Jordan), Megabothris calcarifer gregsoni Holland, Megabothris groenlandicus (Wahlgren), Monopsyllus tolli (Wagner), Oropsylla alaskensis (Baker), Oropsylla idahoensis (Baker), Amphalius runatus necopinus (Jordan).

SITKAN BIOTIC PROVINCE:

Hystrichopsylla occidentalis Holland, Catallagia dacenkoi fulleri Holland, Delotelis hollandi Smit, Myodopsylla gentilis Jordan and Rothschild, Megabothris abantis (Rothschild), Monopsyllus ciliatus protinus (Jordan), Opisodasys keeni (Baker), Thrassis pristinus Stark, Chaetopsylla floridensis I. Fox, Chaetopsylla tuberculaticeps ursi (Rothschild).

Perhaps one of the most startling facts revealed in the list of fleas by biotic provinces is the observation that the Eskimoan Biotic Province (Arctic of other authors) has no fleas that are entirely restricted to this region. All of these species of fleas occur, to some extent, in the taiga or Hudsonian Province, though admittedly certain species do not occupy nearly so wide an area here as in the Eskimoan region. For example, M. groenlandicus has, for all practical purposes, not been reported south of Fort Yukon until this past summer. We found it in the upland tundra at the Danali study site on Microtus gregalis and Ochotona collaris, the latter an accidental host. This flea was reasonably abundant in the Wiseman area during the summer of 1959, and in nearly all instances (with one exception) the host within the taiga region has been Microtus oeconomus, indicating that this microtine rodent is an acceptable host for this flea.

Table XVI. Hosts associated with _Hoplopsyllus glacialis lynx_ in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Lynx canadensis	66	4	16.5
Lepus americanus	35	18	1.9

Table XVII. Hosts associated with _Corrodopsylla curvata curvata_ in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Mustela rixosa	1	1	1.0
Microtus gregalis	5	4	1.3
Sorex arcticus	3	2	1.5
Clethrionomys rutilus	3	2	1.5
Microtus oeconomus	2	1	1.5

Table XVIII. Hosts associated with _Catallagia dacenkoi fulleri_ in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Microtus oeconomus	64	21	3.0
Clethrionomys rutilus	44	24	1.0

Table XIX. Hosts associated with _Peromyscopsylla ostsibirica longiloba_ in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Mustela rixosa	1	1	1.0
Clethrionomys rutilus	14	10	1.4
Microtus oeconomus	182	77	2.4
Mustela erminea	2	1	1.5

Table XX. Hosts associated with Amphipsylla marikovskii ewingi in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Mustela rixosa	12	1	12.0
Microtus oeconomus	8	7	1.1

Table XXI. Hosts associated with Malaraeus penicilliger dissimilis in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Mustela rixosa	1	1	1.0
Microtus gregalis	5	4	1.3
Lepus americanus	2	1	1.5
Ochotona collaris	6	3	2.0
Clethrionomys rutilus	88	36	2.4
Microtus oeconomus	50	35	1.4
Lemmus lemmus	1	1	1.0
Mustela vison	1	1	1.0

Table XXII. Hosts associated with Megabothris calcarifer gregsoni in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Mustela rixosa	1	1	1.0
Microtus gregalis	4	4	1.0
Sorex arcticus	1	1	1.0
Zapus hudsonius	1	1	1.0
Clethrionomys rutilus	13	12	1.1
Microtus oeconomus	39	32	1.2
Microtus pennsylvanicus	3	3	1.0

Table XXIII. Hosts associated with <u>Megabothris</u> <u>quirini</u> in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Microtus gregalis	2	1	1.5
Tamiasciurus hudsonicus	4	1	4.0
Clethrionomys rutilus	80	34	2.4
Microtus oeconomus	21	15	1.4
Erethizon dorsatum	1	1	1.0
Microtus pennsylvanicus	1	1	1.0
Riparia riparia	1	1	1.0

Table XXIV. Hosts associated with <u>Monopsyllus</u> <u>vison</u> in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Clethrionomys rutilus	6	3	2.0
Microtus oeconomus	3	3	1.0
Tamiasciurus hudsonicus	161	51	3.2
Ixoreus naevius	1	1	1.0
Lepus americanus	2	2	1.0

Table XXV. Hosts associated with <u>Orchopeas</u> <u>caedens</u> <u>durus</u> in the study region, summer 1964.

Host	Tot. no. fleas coll.	Pos. no. coll.	Ave. Host
Clethrionomys rutilus	1	1	1.0
Tamiasciurus hudsonicus	148	50	3.0
Microtus oeconomus	2	2	1.0
Mustela erminea	4	2	2.0

With regard to Ceratophyllus l. tundrensis, explanation is difficult because the records known to me in Alaska are mostly from the taiga (subarctic of some authors). This flea has been reported by various individuals from Greenland across to extreme northern Canada. Several of the records from the Palearctic appear also to be from the taiga, which is similar to what I have indicated above. It is perhaps too soon to make a final decision with regards to the species; however, I think that C. l. tundrensis is as equally at home in the taiga as in the Arctic.

Oropsylla alaskensis is monexenous with certain subspecies of the Arctic ground squirrel, Citellus parryi. Throughout most of its range, this flea is restricted to the tundra in the low Arctic or to the upland tundra. However, in its association with Citellus parryi osgoodi, the flea is found in true taiga conditions in the area from Fort Yukon into the Circle Hot Springs area. Within the tundra of the low Arctic, the largest populations of the squirrels seem to be in the riparian habitats, at times dense populations building up along Colville River and its tributaries, where the banks are high enough to prevent flooding during breakup.

Malaraeus penicilliger dissimilis is one of the most widely distributed fleas in Alaska. Apparently, it is equally adapted to members of the genus Clethrionomys or Microtus within the taiga but occurs more frequently on Microtus oeconomus in the northern

tundra regions, perhaps, in part, because Clethrionomys is not as available as a host.

Megabothris calcarifer gregsoni is another widely distributed flea within Alaska. It is of equal abundance on microtine rodents within the taiga, but in the Eskimoan Biotic Province seems to be more closely associated with oeconomus than with any other one rodent. I have more northerly records for this species than I do for Malaraeus penicilliger, but feel no valid conclusion can be arrived at until a more extensive collection has been made.

As indicated earlier, I have never had an opportunity to collect fleas from the various species of lemmings occurring in the Arctic tundra. On the occasions I have been there, the populations have been so low that I have failed to secure these animals in spite of setting out several hundred traps. From what records I have of the microtine rodents, I am led to believe that the infestations of fleas in the most northern parts of Alaska is less than that known to the south in the taiga. Insofar as I know, no studies have been done that would make it possible to compare the density of flea populations in these areas. This type of study would have to be a long range one due to the cyclic fluctuation of the rodent populations.

Holland (1958, 1963) has indicated that Hoplopsyllus glacialis glacialis no doubt occurs in the northern tundra regions of Alaska. I know of no published records to this effect by think that Holland

is probably correct. I have not listed it in this group because of the lack of information concerning its distribution in Alaska. Indeed, Lepus othus is such an uncommon mammal in the northern tundra regions of Alaska that I have known scientist who have worked in the area for years, yet have not seen a specimen of this animal! With such a scarcity of the host, it would seem a tenuous existence for a flea that is so restricted in its host associations.

The five species of fleas listed as Amphi-Eskimoan-Hudsonian are separated in order to emphasize the point that these species do occur inboth areas. In some instances, they apparently have the ability to extend into various types of ecological situations with their hosts, and provide aninteresting contrast to some of the other fleas which appear to be restricted to the same host but which are limited only to the Hudsonian.

The list of fleas for the Hudsonian Biotic Province is perhaps conservative. However, such fleas as Ceratophyllus arcuegens and many other of the ceratophyllids which are known from just one or two records are not included. Probably they are confined to the birds nesting in the taiga, but this must await further observation. Of the fleas restricted to the taiga. I think that Catallagia dacenkoi fulleri, Peromyscopsylla ostsibirica longiloba, and Amphipsylla marikovskii ewingi are perhaps the most interesting. They are usually associated with the microtine rodents within the taiga but do not extend into the northern tundra regions with

them. Those fleas such as *Orchopeas caedens* and *Opisodasys pseudarctomys* that are confined to *Tamiasciurus* and *Glaucomys*, respectively, are apparently limited by the distribution of their hosts and, therefore, are in an entirely different situation from the aforementioned microtine fleas.

Of some interest is the fact that three species of the genus *Oropsylla* are known to occur. In view of the previous discussion concerning *O. alaskensis*, no further comment will be made concerning this species. *Oropsylla arctomys* is confined to the woodchuck, and I only know of two records of this animal being infested in Alaska. It is perhaps somewhat presumptive on my part, but I seriously doubt that either the woodchuck or this flea will be found beyond the taiga. *Oropsylla idahoensis* is for the most part restricted to the upland tundra, and its existance in the taiga is a more or less marginal one.

Two speciesof *Chaetopsylla*are known for this region, and both are also known in the Sitkan Biotic Province, which is a rather unusual distribution insofar as Alaskan fleas are concerned. One of them, *C. floridensis*, is associated with mustelids, and the other one, *C. t. ursi*, is associated with various species of Ursidae. I have included several species of the genus *Ceratophyllus*, most of them being restricted to the Hirundinidae. It may well be that such species as *C. riparius* extend a short distance into the Arctic tundra regions. However, I anticipate this would only

be a "fringing" phenomenon. It would be interesting to see if Ceratophyllus c. celsus is prominent in the nests of the bank swallow in southeastern Alaska. As Holland has stated in several of his publications, the bird fleas of the northern regions are poorly understood, and I suspect that most of the new species to be found within Alaska will be those fleas that parasitize an avian host.

In the earlier part of this work, mention was made of the problem of attempting to associate upland tundra with that of the Arctic Slope, indicating that while in a general sense they appear similar, they are a different type of ecological community. Four of the eight species of fleas listed for this region are for all practical purposes restricted to it. As to whether this is because flea larvae are adapted to the particular ecological environment offered in the upland tundra, or whether the fleas have become so closely associated with the host that they are unable to adapt to other animals, is not known to me. However, I suspect that this is probably an example of a close association with a particular host. Stray records of microtine fleas upon Ochotona collaris are occasionally reported, but the pika fleas Ctenophyllus terribilis and Amphalius r. necopinus invariably are restricted to that host. The record of Nosopsyllus fasciatus at Nome (Shiller, 1956) is an incongruous one. It is, along with its host, Rattus norvegicus, an introduced species and could not survive without the protection afforded by this edificarian habitat.

Monopsyllus tolli is also ordinarily associated with pika, although the one Alaskan record is from ptarmigan, presumable in a pika habitat.

Oropsylla idahoensis is largely confined to the upland tundra situated in the southern regions of Alaska, the squirrel *Citellus parryi plesius* not penetrating to any significant depth into the taiga, although another subspecies, *S. u. ablusus*, does. The rest of the species were discussed earlier and have been encountered in two of the Biotic Provinces.

The fleas encountered in the Sitkan Biotic Province are for the most part distinctive for this region. Published information on the mammals and other animals of the region are not nearly so conspicuous as those reported for the other areas of Alaska. The occurrence of *Chaetopsylla floridensis* was somewhat surprising; however, the adjustment of the flea to an environment such as that found in southeastern Alaska as compared to central Alaska is perhaps no greater than that of the locality for the type specimens in Florida. Most of the fleas found in the Sitkan Province are known further south in the Pacific Northwest.

ORIGIN OF ALASKAN FLEAS: The 52 species and subspecies of fleas reported here have been derived from three principal sources. The first group to be discussed is considered as the Transcontinental Group, which has largely pushed north and westward into Alaska as post-Pleistocene immigrants. The second, and the largest group,

is termed Amphi-Beringian, and the fleas are thought to have been derived from the Palearctic Region. The third, and the smallest group, are the fleas derived from the Pacific Northwest and are confined to a relatively narrow strip of land in southeastern Alaska. It is realized that several species of bird fleas (*Ceratophyllus*) could have been included; however, I have had experience only with a limited number of these fleas, three of which are included in the following discussion. The reader is referred to Holland (1963) for the additional species in this group.

TRANSCONTINENTAL GROUP: *Hoplopsyllus glacialis lynx* (Baker), *Corrodopsylla curvata curvata* (Rothschild), *Epitedia wenmanni* (Rothschild), *Ceratophyllus riparius* Jordan and Rothschild, *Ceratophyllus idius* Jordan and Rothschild, *Ceratophyllus scopulorum* Holland, *Megabothris quirini* (Rothschild), *Monopsyllus vison* (Baker), *Orchopeas caedens* (Jordan), *Opisodasys pseudarctomys* (Baker), *Oropsylla arctomys* (Baker), *Chaetopsylla floridensis* I. Fox.

H. g. lynx is a common flea on the varying hare in the major portion of this animal's distribution. Miller (1962) reported this flea from Vermont, although Geary (1959) and Benton (personal communication) have not found it in New York, in spite of the fact that several specimens of the varying hare have been examined. It is perhaps a bit rash to assume that this flea is a post-Pleistocene migrant into the Alaskan area; however, inasmuch

as only *H. g. profugus* Jordan is known in the Palearctic, I consider *Hoplopsyllus* to have been Nearctic in origin and to have migrated westward in Eurasia sometime during the existence of the Bering land bridge. *H. g. profugus* was originally described ex *Lepus capensis tolai* in the Ilijskaya Valley, Kazakhstan. Ioff and Scalon (1954) indicate that it is known from the Sayanskii Mountain Range in Tuva, in northwestern and southern Khangsj, and in Taishiri, Mongolia. *H. g. lynx* has not yet been reported in the extreme southern extensions of the varying hare's range.

C. c. curvata is a widely distributed flea in the Nearctic Region and is restricted to various species of the Soricidae. The genus is represented in the Palearctic Region; however, the closely related species are all Nearctic.

E. wenmanni has an extremely broad distribution in the Nearctic Region and apparently is an example of a flea that exceeds its primary hosts in distribution. Throughout most of its range, this species is confined to the genera *Peromyscus* and *Neotoma*. *E. wenmanni* is known from Mexico into the central region of Alaska. While some species of *Peromyscus* occur in southeastern Alaska (Sitkan Biotic Province), to date, this flea has not been reported there. In the interior of Alaska, it occurs sporadically and seems to be more commonly associated with *Microtus oeconomus* than any other rodent. Hubbard (1960) reported it from as far north as Kivalina, though I feel that this is an incongruous record.

M. quirini has probably returned into the Alaskan area with the northern migration of Microtus pennsylvanicus and Zapus hudsonius. It is found throughout the interior of Alaska, being established in the Tanana Valley and on into the southwestern portion of the state. As Holland has pointed out in several of his publications, this flea bears very close resemblance to Megabothris groenlandicus and can be considered as allotropic to it. Previous to this summers study I knew of no area where these two species overlapped within Alaska. Our records this summer occurred at the Denali study site, but are tenuous because the record of M. quirini is based solely upon female specimens, which are not completely reliable as to taxonomic characteristics. Both Monopsyllus vison and Orchopeas caedens are associated with Tamiasciurus. While Monopsyllus is known to occur in the Palearctic Region, Orchopeas is not so represented.

O. pseudarctomys is associated with Glaucomys and Tamiasciurus, and like Orchopeas is a New World genus. Both the host and the flea are of Nearctic distribution; however, the flying squirrels as a group have a far greater distribution and evolution in the Palearctic Region than that known in the New World. Frequently, Glaucomys shares a flea (T. o. coloradensis) with Tamiasciurus, which is of Old World origin, being primarily a parasite of the squirrel Sciurus vulgaris. This is indeed an interesting association, because one would expect coloradensis to occur on the Nearctic species of Sciurus. In the event that Glaucomys was of

Eurasian origin, it had to be at a time when the land bridge across the Bering Strait was favorable for tree growth. If Hopkins (1959) is correct in his concepts, this would imply a date earlier than the Pleistocene.

O. arctomys is associated with the woodchuck, Marmota monax, throughout its range in the Nearctic. The host is not a common animal in the interior of Alaska, and, consequently, numerous collections of this flea have not been encountered. I think that it is a relatively recent migrant into the boreal region, judging from the rather restricted distribution in Alaska. With regards to the distribution and/or origin of C. floridensis little can be said at the present time. Collection records show two widely separated regions within North America. With one possible exception, it does not seem to be more closely related to Palearctic forms than those occurring in the Nearctic fauna. However, it is perhaps closer to C. alia Ioff, described from the sable, Martes zibellina. Ioff and Scalon (1954) indicate that alia has been found in small numbers on sables in western Siberia, but that the true host and the area of distribution of alia is not known with certainty. I have only the illustrations of the above mentioned Russian workers to compare with my material, and it is therefore difficult for me to indicate just how close the relationship may be. Certainly, there are many parallels in the lack of distribution records for these two species of fleas. Future studies may well indicate that alia and floridensis are conspecific.

I have included _C. riparius_ in the Transcontinental Group, although it is known to occur in eastern Siberia. However, the distribution in the last mentioned area is relatively small, and unless specific concepts within the genus _Ceratophyllus_ are changed, I have little choice but to assume that _C. riparius_ is of Nearctic origin. Smit, (1956, p. 144) has indicated that perhaps _riparius_ is not more than subspecifically distinct from _C. styx_. Smit's suggestion is more acceptable to me than the one proposed by Benton and Shatrau (1962) that _C. riparius_ and _C. styx_ is one of the relatively rare cases in which the evolution of the parasite has proceeded more rapidly than that of the host. This problem will have to await an extensive study by a competent authority.

Benton and Shatrau (1962) reported _C. scopulorum_ from New Brunswick in the nest of both the cliff swallow (_Petrochelidon pyrrhonota_) and the barn swallow (_Hirundo rustica_). Previous to these records, _C. scopulorum_ was known only from the Northwest and Yukon territories of Canada. These authors indicated the eastern populations of this flea agreed extremely well with the original description by Holland (1952). Alaskan specimens also agreed well with the original description, indicating that this flea is not as pleomorphic as some of the other species within the genus. Benton and Shatrau (_ibid_) also reported a large series of _C. idius_ from the nest of the barn swallow, and only a few specimens from nests of the tree swallow (_Iridoprocne bicolor_)

a bird that is usually associated with this flea. From the description, I cannot tell if the scopulorum and idius cohabited the same nests of the cliff swallow or if they were in different ones.

AMPHI-BERINGIAN GROUP: Catallagia dacenkoi fulleri Holland, Peromyscopsylla ostsibirica longiloba (Jordan), Amphipsylla marikovskii ewingi I. Fox, Amphipsylla sibirica pollionis (Rothschild), Malaraeus penicilliger dissimilis (Jordan), Megabothris calcarifer gregsoni Holland, Ctenophyllus armatus terribilis (Rothschild), Ceratophyllus lunatus tundrensis Holland, Amphalius runatus necopinus (Jordan), Tarsopsylla octodecimdentata coloradensis (Baker), Oropsylla alaskensis (Baker), Chaetopsylla tuberculaticeps ursi (Rothschild).

Several individuals in the past have been interested in the relationship of the boreal Nearctic fleas with those of the Palearctic Region. Most important among these workers have been Wagner (1936) and Holland (1949, 1958, 1963). Inasmuch as Holland's papers are widely circulated, the reader is referred to these excellent papers for additional background. Wagner's publication, on the other hand, has frequently been overlooked. Therefore, the following brief review of his concepts is presented. Wagner was instrumental in laying the foundation for this concept in his definition of a "vicariating species" (equivalent to an ecological homologue). For example, Wagner noted that A. s. pollionis,

T. coloradensis, C. niger, and Chaetopsylla (Arctopsylla) ursi occurred in both the New and Old Worlds. Wagner also mentioned that Corrodopsylla c. curvata and Corrodopsylla birulae Ioff replaced one another in the New and Old World. He suggested that Ctenopsyllus terribilis was nearest to C. subarmatus Wagner from Altai, thus being a connecting link between the fauna of British Columbia and that of East Asia. Wagner noted M. vison was near M. sciurorum Schrank, thinking it replaced the latter flea in North America upon the squirrels of the genus Sciurus. Most notable of his comments in this paper were his remarks concerning H. g. lynx, H. g. glacialis and H. g. profugus.

Of the twelve species listed in this group, six have been carried across the Bering land bridge by the microtine rodents, Clethrionomys and Microtus. On the basis of information now available to me, it is literally impossible to discern which animal, Clethrionomys or Microtus, was the primary host of the Nearctic forms. Of the six, only two have a distribution beyond the taiga, these being Malaraeus penicilliger dissimilis and Megabothris calcarifer gregsoni. Two other genera, Amphalius and Ctenophyllus are each represented by one species, both of which occur upon the same host, Ochotona collaris in the upland tundra. Preliminary studies have indicated there is a basis to think that the populations of Amphalius runatus necopinus have evolved into at least two subspecies on the two disjunct populations of Ochotona occurring in the Nearctic Region. Such

evidence is not available for Ctenophyllus armatus terribilis. The fleas belonging to these two genera are believed to be Eurasian in origin because of the larger number of species occurring in the Palearctic Region at the present time, and also by the fact that the pikas are distinctly more diversified as to ecological range and speciation.

T. o. coloradensis is represented in the Old World by the nominate form, which has an extremely broad distribution with Sciurus vulgaris. In the New World, T. o. coloradensis is largely restricted to the northern and western areas of Tamiasciurus, though associated also to some extent with Glaucomys. No records of this flea have been published for the eastern part of the United States. Apparently, coloradensis adapted to a new boreal host on coming to the New World, inasmuch as it is now known to be associated with squirrels of the genus Tamiasciurus, but not Sciurus.

O. alaskensis is apparently as host specific in eastern Siberia as it is in the New World, being confined to Citellus parryi. The fact that this squirrel flea is apparently inseparable from the Eurasian form speaks for the relatively recent crossing of these two stocks. Chaetopsylla t. ursi is likely to be known as conspecific with tuberculaticeps within the near future. The fact that certain of the hosts are still able to migrate across the Bering Sea during the winter months would lend considerable weight to such a concept.

PACIFIC NORTHWEST: Hystrichopsylla occidentalis Holland, Catallagia dacenkoi fulleri Holland, Delotelis hollandi Smit, Mydopsylla gentilis Jordan and Rothschild, Megabothris abantis (Rothschild), Monopsyllus ciliatus protinus (Jordan), Opisodasys keeni (Baker), Thrassis pristinus Stark.

This group of fleas is essentially analagous to what Holland has called Cordilleran Group B and Vancouverian Group. I regard these fleas as having originated from the Pacific Northwest refugium that existed during most, if not all, of the Pleistocene. Upon the retreat of the Cordilleran glacier, these fleas have migrated east, south, and north, from this center, but are still confined, or essentially limited, to the western half of the United States. Certain of these species, for example, Catallagia charlottensis and Monopsyllus ciliatus protinus, are not known east of the Coast Mountains (Range) in British Columbia. Within Alaska, they are confined essentially to the Sitkan Biotic Province.

Acarina

Ixodoidea. Of the seven species of ticks known by me to occur in Alaska, three have been introduced, and only one of these apparently has become established, two are host-specific for marine or shore birds, and the remaining two are parasitic upon mammals. Of the last two, only one is found in the interior of Alaska.

Because of the lack of information concerning this medically important family of arthropods, a brief review will be given for each species. I have three records of Dermacentor andersoni Stiles occurring in Alaska. Two of these are from Fairbanks and were taken from dogs known to have been shipped from the lower part of the United States within a relatively short period of time. The third record comes from Cape Thompson and no doubt was a contaminant in someone's field gear. I believe the record of Dermacentor variabilis Say is quite likely an erroneous record. Since it was reported by Banks some fifty years ago, no other additional records have come to light. It is entirely likely, with the exchange of military personnel back and forth between various parts of the United States and Alaska, that occasional, accidental, records for this species will occur. It seems highly unlikely that either D. andersoni or D. variabilis will become established in the interior of Alaska in the forseeable future because the dogs are not allowed to roam at will on the military bases. On the contrary, they are strictly curtailed. Ixodes signatus Birula is mainly restricted to marine birds, of which the cormorant appears to be the true host. However, there is one record from the Pribolof Islands, taken by G. C. Carl, in 1949, which records the host as Leucosticte sp. (rosy finch). It is a large species with a wide distribution, having been reported in California, the Aleutian Island, and Japan. Ixodes uriae White is a true parasite of marine birds. This particular

species has a cosmopolitan distribution, having been reported from Europe, Asia, Australia, and North America. From what is known of its distribution in North America, it has been taken more frequently in Canada, on both the Atlantic and Pacific coasts. Because of the poorly developed armature of the hypostomes in the males of this species, as well as _I. signatus_, they are thought to be nest inhabitants and that the males do not feed.

Ixodes angustus Neumann is a holarctic species, having been reported from southeastern Siberia and from the Kurile Islands. On the basis of our present knowledge, it enjoys its widest distribution in North America, particularly in the northern portion of the United States and southern Canada. It is one of the commonest species of _Ixodes_ in British Columbia and along the Pacific Coast it ranges from Alaska to California. In Alaska, it occurs in the wet belt, west and south of the Alaska Range. As nearly as I can tell from published information, it occurs only in the wetter portions of the northern regions. Large numbers of all stages are frequently taken on various species of animals; among which are _Glaucomys_, _Tamiasciurus_, _Microtus_, _Clethrionomys_, _Sorex_, and _Ochotona_. Up to the present time, in spite of having taken some thousands of voles in the central region of Alaska, I have not encountered this tick.

Rhipicephalus sanguineus (Latreille) is an introduced species to the Nearctic Region, and only in the past few years has it be-

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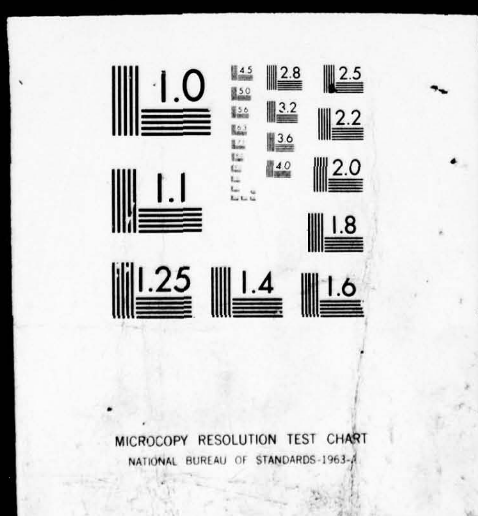


come established in Alaska. Inasmuch as it is dependent upon the edificarian type of habitat, no doubt it will remain in Alaska for some time to come unless stringent control measures are applied to it. However, inasmuch as this tick (as we know it in the Nearctic Region) is host-specific for the domestic dog, there seems little chance that it will spread to other animals. It has become abundant enough in certain of the living quarters on military bases in Alaska to be classified as a pest species.

The seventh species of tick will only briefly be mentioned here because the bulk of the remaining discussion concerning the Ixodoidea will deal with this species. Haemaphysalis leporis-palustris (Packard) is known to have a broad distribution in North America, as illustrated in Figure 12. Several investigators in the past, including Frances, Green, and Jellison, have reported that this tick was one of the principal reservoirs of tularemia in nature and that it has contributed immeasureably to the spread of this disease among wild lagomorphs and birds. The rabbit tick (Haemaphysalis laporis-palustris) infests numerous species of lagomorphs, gallinaceous, and passerine birds throughout its distribution. The most important hosts in central Alaska are the varying hare, members of the family Tetraonidae (grouse), and various species of passerine birds. Among the Tetraonidae, the willow ptarmigan (Lagopus lagopus) was the most commonly infested. A few specimens have been removed from the red squirrel (Tamiasciurus hudsonicus), but generally not more than one or two

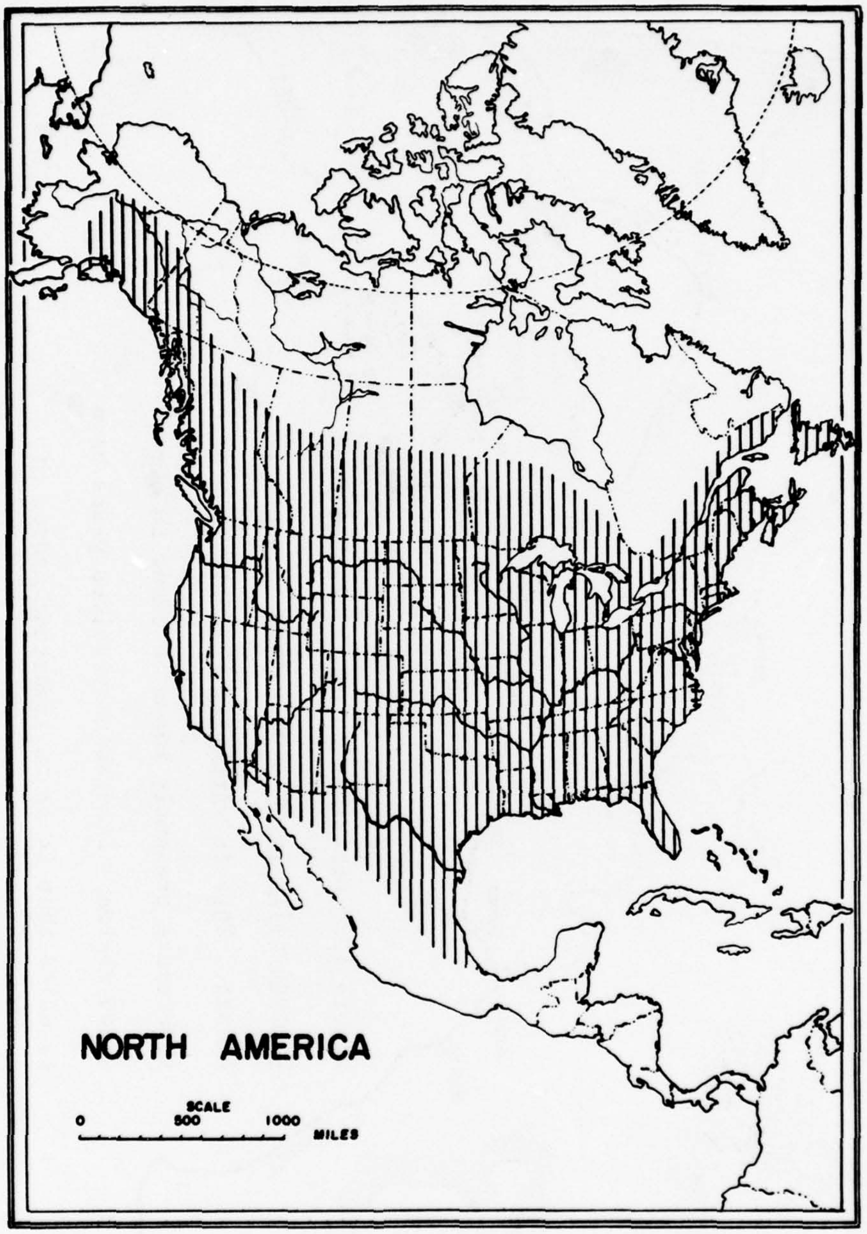


Figure 12. Distribution of the rabbit tick, Haemaphysalis leporis-palustris in North America. This tick is unusually host specific being confined, for the most part, to the Lagomorpha. However, the immature stages are encountered upon various species of birds.

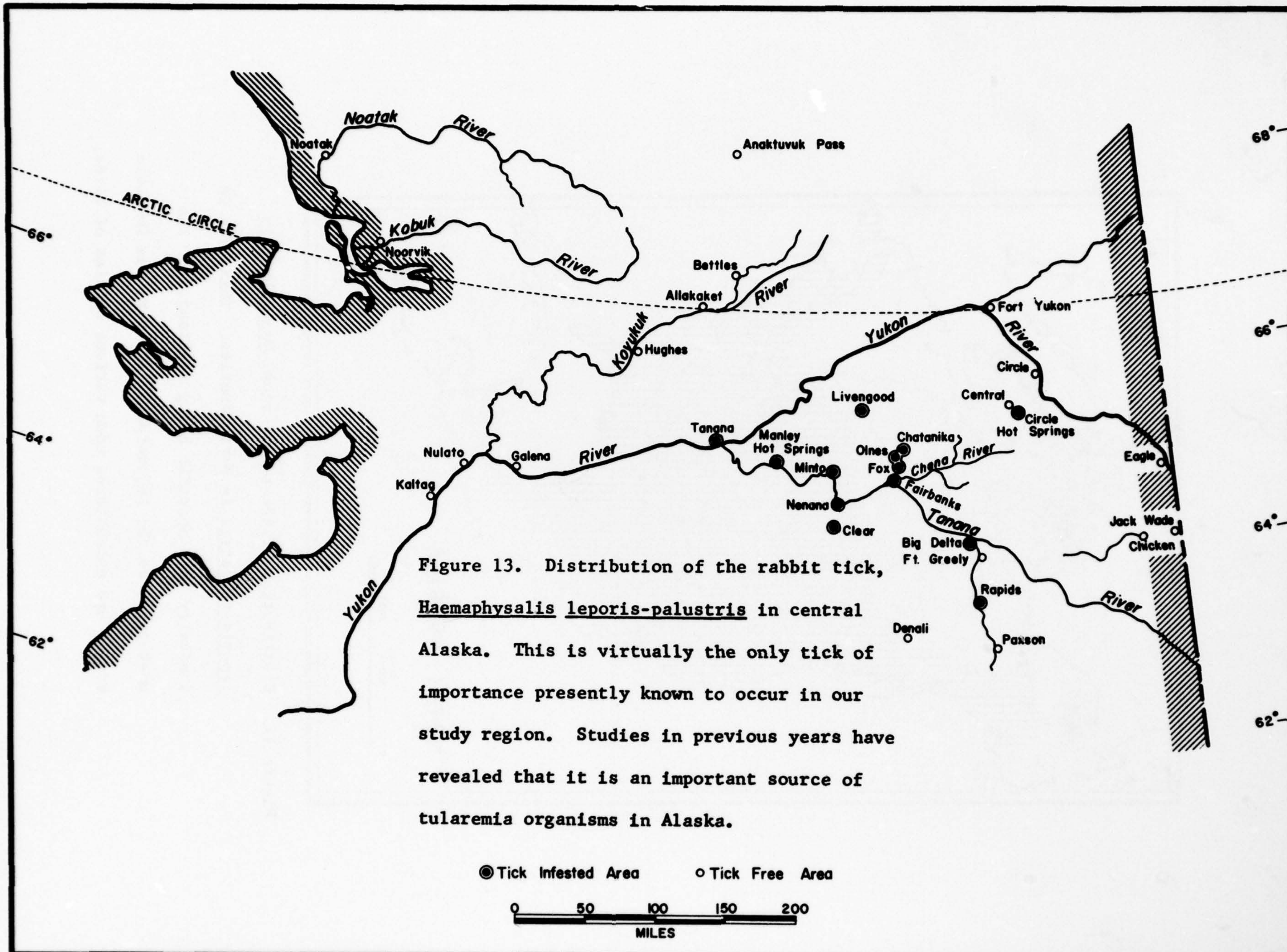


Figure 13. Distribution of the rabbit tick, Haemaphysalis leporis-palustris in central Alaska. This is virtually the only tick of importance presently known to occur in our study region. Studies in previous years have revealed that it is an important source of tularemia organisms in Alaska.

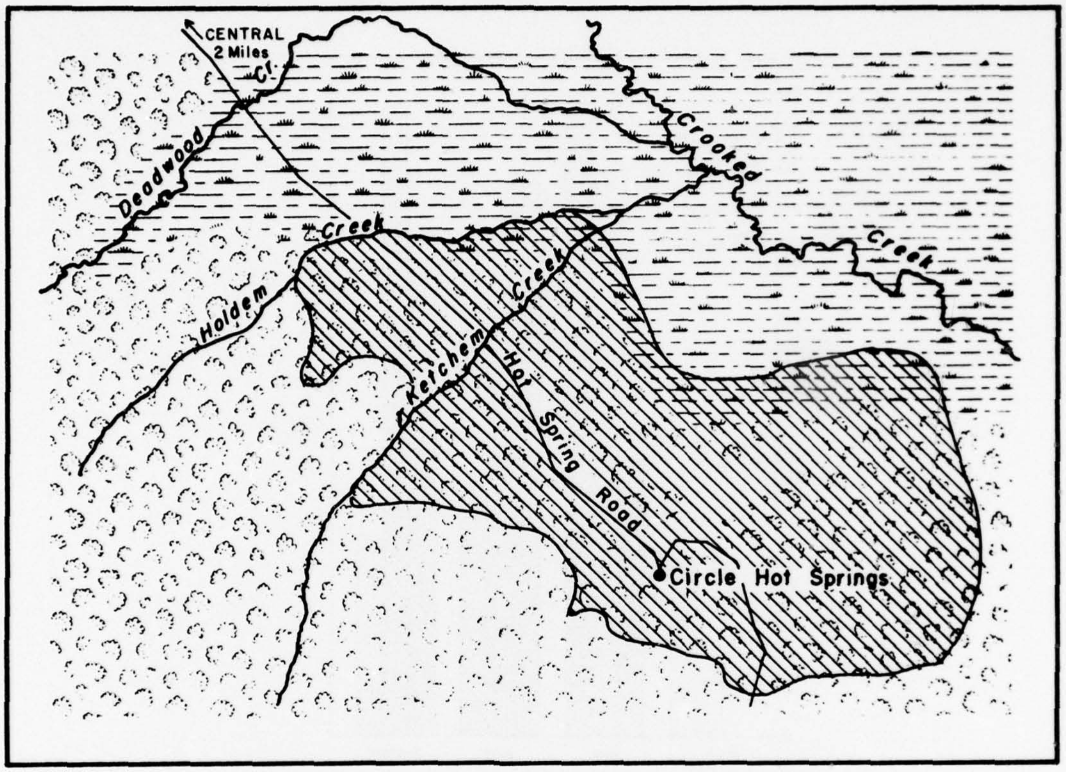
per animal. As nearly as I can recall, we have only found two specimens of ticks actually attached to the squirrel. The remaining observations have been made as they were crawling around on the animal after having been bagged for an hour or more. The voles are thought to be not important, inasmuch as I have never found an animal with this tick attached to it. Indeed, I have yet to find the first tick-infested vole within the interior of Alaska, regardless of whether it is the rabbit tick or some other species. However, in September of 1964, a Zapus hudsonius was found with one nearly engorged larva firmly attached to the ear.

Figure 13 represents the known distribution of the rabbit tick in Alaska. Insofar as I know, there are no published records for this species occurring in southeastern Alaska, nor have I had any direct communication from anyone indicating that it is there. I do not know for a certainty that it is absent from southeastern Alaska, and would think this somewhat unlikely. Be that as it may, the distribution within central Alaska is not a uniform one. I have never taken it where the taiga fringes into the upland tundra, and as is illustrated in Figure 14, the distribution within the taiga is sporadic. The cause for this sporadic distribution is not understood at this time, but on the basis of general ecology, no significant differences have been noted between the tick-free areas and the tick-infested ones. The distribution at Circle Hot Springs is one of the most graphic. Perhaps this cannot be taken as a typical example, inasmuch as it is the northernmost

known point in its distribution. It is significant, however, that Geary (1953) did not find ticks at Central, nor at Circle City, which are duplicates of my findings from 1955 through 1962. As one proceeded up the mountains to the west of Circle Hot Springs the higher terrain soon contained hares that were free of ticks. Of the few studies that have been made dealing with the home range of the varying hare, this focus of infestation, approximately a mile to a mile and a half in length and a mile wide, is certainly not nearly as large as the area covered by this hare.

The largest known area supporting ticks in Alaska is in the Fairbanks region. Here a vast area has an infestation, though even within this there are small pockets in which the hares seem to be relatively free of ticks.

A study of past records of this particular species of tick collected during the months of May through August is interesting (Fig. 15). I do not have sufficient records for remaining months to make any sort of a valid analysis. I know that the ticks are active throughout most of September, but for the few animals taken from October through April, the results have been negative. The peak of adult activity with engorged females, occurs in May and June. The larvae are most abundant in July and August, and the nymphs most abundant in August. The fragmentary data for September indicate that the larvae and the nymphs are quite active



Scale: 1 mi.

Figure 14. The distribution of the rabbit tick is sporadic in central Alaska. At the Circle Hot Springs study area a heavy infestation of the varying hare occurs in the shaded area, yet the hares have been free of ticks at Central and the wooded areas beyond. The cause for the spotty distribution is not known.

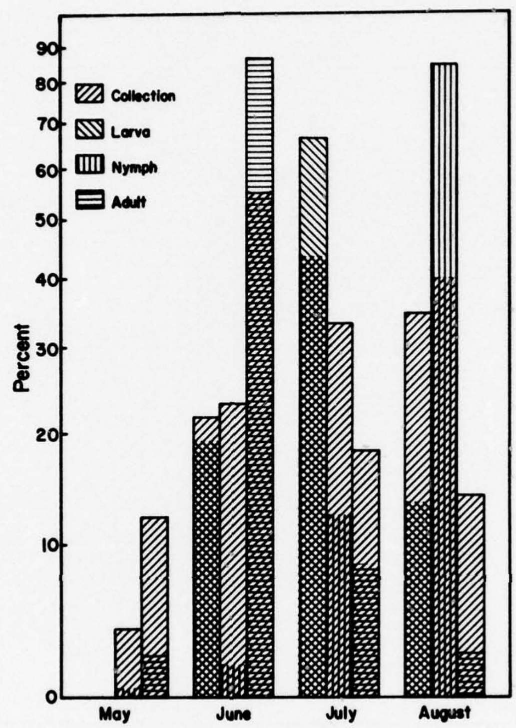


Figure 15. The occurrence of the rabbit tick by month. The numbers of specimens collected per instar and the number of times each instar was encountered are expressed as a percentage for each month. Data for this figure are based upon 458 collections and 4,359 specimens from June of 1955 to September of 1957.

at this time. Correspondence with other workers who have collected this tick in Alaska reveal that they have no knowledge of the larvae occurring in May. I am led to believe that the larvae do not overwinter but that the nymphs and the adults do. One pertinent point in the biology of this tick which is not understood at the present is how its populations are maintained in any sort of a reasonable number during the years when the varying hare is at the low ebb of its cycle. When the populations of hares have crashed, there are as many as two, possibly three years, when they are so scarce that one can spend a considerable amount of time attempting to capture a specimen and may fail to see a single one. I do not believe that hares are abundant enough at these times to account for the maintenance of the tick.

As illustrated in Table 26, we did find several larvae and nymphs on passerine birds this summer. However, as to how long or how many seasons the nymphs and adults may survive without a blood meal is a question that remains unanswered. Camin (pers. comm.) is of the opinion that none of the birds are important as hosts for the adults. Within Alaska, considerably more study is needed since so little information is known about this point. During the summer of 1955, I did find grouse heavily infested with immature stages and removed a total of six engorged females from four of these fowls. These ticks laid viable eggs, and I was partially successful in establishing a laboratory colony. While I have none of these specimens preserved in alcohol (they were used for micro-

Table XXVI. Hosts and distribution of *Haemaphysalis leporis-palustris* in the study region, summer 1964.

	Manley Hot Springs	Circle Hot Springs	Dot Lake	Nenana Hwy.	Livengood
Melospiza lincolnii	9-VIII 5 L 12-VIII 13 L				
Passerella iliaca	10-VIII 3 L 4 N 13-VIII 1 L 2 N				
Zonotrichia leucophrys	12-VIII 1 N 13-VIII 7 L 1 N	30-VIII 1 N			
Hylocichla ustulata	12-VIII 1 L 13-VIII 11 L 1 N 14-VIII 1 L 1 N				
Hylocichla guttata	13-VIII 2 N				
Spizella aborea		29-VIII 29 L 8 N 30-VIII 16 L 5 N 1-IX 21 L 3 N 3-IX 3 N			
Junco hyemalis		30-VIII 4 N 1-IX 1 N			
Turdus migratorius				11-VII 3 L 3 N	
Petrochelidon pyrrhonota	11-VIII 1 N				
Zapus hudsonius					12-IX 1 L
Lepus americanus		2-IX 10 N	4-VII 1 ♀ 4-VII 3 ♂♂ 2 ♀♀	11-VII 16 L 3 N 8♂♂	12-IX 47 L 22 N 1 ♂ 1 ♀

L = larvae

N = Nymphs

biological assay work), I have little reason to question but that they were Haemaphysalis leporis-palustris, and not the closely related species, Haemaphysalis chordeilis, which is a common bird tick in all but the wet coastal belt of Canada, occurring abundantly on the upland game birds. The progeny from these females engorge readily in both the larval and nymphal states upon varying hares, at which time work concerning their feeding habits was discontinued.

From the evidence available in the foregoing account, and based upon the temperatures underneath the snow cover (Pruitt, 1957), it appears likely that unfed nymphs and adults overwinter and attach during the latter part of April and May, depending upon the locality and season, in Alaska. No data have as yet been obtained to indicate whether nymphs and adults which do not find a suitable host during the first summer can overwinter a second or third season. Such information is available for some of the more common hard ticks, such as andersoni, in Montana. On the basis of available information, it seems likely that it takes two seasons, and possibly three, for the completion of the life cycle in Alaska. Only under fortuitous conditions could the life cycle be completed in less time than that. Why the nymphs are not found in any numbers before July and August is unknown to me; it may lie with inadequate collecting rather than with the biology of the tick.

Philip first reported this tick naturally infected with tularemia organisms in 1939. Philip _et al_. (1954), testing a small series of ticks, found four pools infected with tularemia organisms. Both the findings in 1939 and those reported in 1954 were taken in the Farmers Loop area, which has also contributed a number of human cases within the Fairbanks region. It is interesting that of the large series of ticks collected by me, only two pools were found infected.

The first pool of infected ticks was taken at Wilbur Creek on July 28, 1957, and consisted of 150 nymphs in various stages of engorgement which were removed from two willow ptarmigan, _Lagopus lagopus_. Gross pathology of both of these ptarmigan in the field indicated nothing pathogenomic for tularemia. The ticks were retained in special rearing vials, where they molted to the adult stage and were allowed to fast for approximately two months. At this time, a small portion of the ticks were placed upon domestic rabbits and guinea pigs in an attempt to establish a larger colony of Alaskan _H. leporis-palustris_. These attempts met with failure, inasmuch as the ticks refused to attach in significant numbers. This was not too surprising, since I had noted this same condition some years earlier when attempting to feed another tick, _Dermacentor parumapertus_ Neumann. Previous studies had also indicated that when using strains of the rabbit tick from Kansas and Oklahoma, the results were inconsistent when attempting to feed them on domestic rabbits; yet no difficulty was

encountered when using native cottontails, the natural host.

For these reasons, several cottontail rabbits (Sylvilagus floridanus alcer) were live-trapped near the University of Oklahoma. They were retained in the laboratory for four weeks in an attempt to get them adapted to the laboratory, and secondly, if they were infected with pathogenic organisms, to allow these a chance to reveal themselves before utilizing these animals for experimental work.

Twelve adult ticks, equally divided as to sex, were placed on the ears of the three rabbits. On the sixth and eighth days after attachment, two of the rabbits showed signs of definite illness. On the eighth and tenth days after attachment, both sick rabbits were dead. Autopsy revealed characteristic lesions for tularemia on the liver and spleen. Portions of these organisms were removed, ground in sterile saline solution and one ml of the resultant suspension was injected intraperitoneally into each of four guinea pigs. Within 96 hours, all guinea pigs were dead. Plate cultures made from the spleens of these animals showed the characteristic growth of Francisella tularensis. A gram stain of the organisms removed from these colonies revealed small pleomorphic gram-negative organisms. This information, along with the characteristic findings during autopsy, assured me that these organisms were the etiological agents of tularensis. The remaining ticks which had been retained in vials were then immersed in a 5 percent

solution of phenol for 20 minutes, washed in several changes of distilled water, and ground in sterile, normal saline. One ml of the resultant suspension was injected intraperitoneally into each of six guinea pigs. Within nine days, all but one guinea pig was dead. Post-mortem examination, colony growth, and gram stain were all characteristic of F. tularensis. The one remaining guinea pig died on the fifteenth day, and the findings during autopsy were typical of tularensis.

With this information at hand, it seemed adviseable to attempt an LD_{50} titration. The formula of Reed and Muench (1938) was followed, with six animals being used at each dilution. The spleens from three of the above mentioned guinea pigs were ground, as mentioned earlier, with serial ten-fold dilutions made of the resultant suspension. Guinea pigs, Swiss white mice, and cottontail rabbits were utilized in the titration. Table 27 shows the results of this titration. These results indicate that the strain of

Table XXVII. The LD_{50} of Francisella tularensis isolated from Haemaphysalis leporis-palustris.

Host	LD_{50}
Guinea pig	$10^{-4.0}$
Mouse	$10^{-4.0}$
Cottontail rabbit	$10^{-4.5}$

tularemia isolated from the rabbit rick was of relatively low virulence. Insofar as I know, this was the first time an LD_{50}

titration had been made of tularemia organisms from Alaska, and is also the first time that infected ticks were removed from gallinaceous birds in this area.

During the spring of 1962, while engaged in other research in Alaska, I found a number of varying hares near College which had apparently died of natural causes during the month of May. Death was so recent in three of these animals that I placed them in bags and brought them into the laboratory. Ticks were recovered from two, and autopsy revealed findings suggestive of tularemia organisms. While no facilities were abailable for detailed LD_{50} titrations, the ticks were ground as mentioned previously and injected into guinea pigs. Of the six guinea pigs injected, all died within 96 to 122 hours. Autopsy revealed the characteristic enlargement of the spleen, with the abundance of small, cloudy white spots being present. I am convinced in my own mind that these ticks were infected with tularemia organisms and that the hares were also infected, but I cannot say that the tularemia organisms produced their death. Other unpublished findings (Alaskan data) on tularemia organisms will be reported in the microbiological assay section.

Sufficient evidence is not available to discuss the mesostigmatic mites that occur on the various species of mammals within Alaska. A small list is included in Appendix A, which has been gleaned from the literature and from my own personal records. I

have some evidence to indicate that one species (*Laelaps multispinosus* Banke) can be involved in the transmission of tularemia organisms among the muskrats. However, much work yet remains to be done before this mite is clearly incriminated as an efficient vector.

Culicidae

Alaskan mosquitoes can be placed in two groups, depending upon the kind of life cycle that they undergo. Wesenberg-Lund (1921) established four types of life cycles for the mosquitoes of the world. These four types have withstood the test of time, except for one modification to be mentioned below. The first type, the *Aedes cinereus* form of life cycle, is typified by all of the Alaskan *Aedes* because hibernation or overwintering takes place only in the egg stage. The eggs, larvae, and sometimes the pupae, are cold-tolerant forms. This is the only type of life cycle known for those mosquitoes which inhabit the arctic slope. A fifth type of life cycle was proposed by Frohne (1953, 1954), in which hibernation is accomplished in the adult stage and differs from the fourth type described by Wesenberg-Lund and by Bates (1949) only in the fact that the females, although inseminated before hibernation, do not take a blood meal at this time. Actually, recent information by various workers indicates that this behavior may be true of many female mosquitoes which successfully survive the winter in the temperate regions. Frohne further believed that the mosquitoes with this type of life cycle were again single brooded. In the

interior of Alaska only the mosquitoes that are placed in the genera *Anopheles*, *Culex*, and *Culiseta*, have the latter type of life cycle. In actuality, these constitute a very small proportion of the total mosquito fauna as we know it.

Much has been said about the cold-hardiness of Alaskan mosquitoes without the writers really understanding the actual ecology of the matter. Pruitt (1957) reported on temperatures beneath the snow in the taiga of Alaska, and it is extremely significant that once about 20 centimeters of snow have accumulated on the ground, the temperature next to the earth does not get lower than 16°F. My observations have shown that the mosquitoes of the genera *Culiseta* and *Culex* (from this I infer also *Anopheles*) hibernate below the snow in clumps of grass such as *Calamagrostis*, very close to the ground. I have never found any adult Alaskan mosquitoes that were able to withstand temperatures below 0°F. in the laboratory for any prolonged period of time.

Of all the boreal insect species, without doubt the most offensive ones insofar as man and many other mammals are concerned are the slightly more than two dozen species of mosquitoes. Apparently, the mosquito problem in Alaska has changed very little since it was first recorded by the early trappers and explorers. It is not meant to imply that the mosquito season is the same each year, because it does vary with the abundance of the total population and with the given species being dominant in any one year. There

are times in Alaska when the mosquito population is not any greater than it is in many parts of the temperate regions; however, in some years, the mosquitoes have occurred in intolerable numbers and thus have accounted for some graphic writings by early explorers. The following brief account is given by three early scientists in order to provide something of an insight into what the situation was in Alaska and in northern regions before the invasion by European populations.

In 1880, Petrov investigated the resources in Alaska and in 1900 published his findings. He found the mosquitoes to be an extremely severe annoyance in the Kuskoquim Valley, and the following is a brief excerpt from his writings:

> "There is another feature in this country, which though insignificant on paper, is to the traveler the most terrible and poignant infection that he can be called upon to bear in the new land. I refer to the clouds of blood-thirsty mosquitoes, accompanied by a vindictive ally in the shape of a small, poisonous blackfly, under the stress of whose persecution the strongest man with the firmest will must either feel depressed or succumb to low fever . . . . The traveler who exposes his bare eyes or face loses his natural appearance; his lips swell up and close, and his face becomes one mass of lumps and fiery pimples. Mosquitoes torture the Indian dogs to death, especially if one of these animals, by mange or otherwise, loses an inconsiderable portion of its thick, hairy covering, and even drive the bear and the deer into the water."

Abercrombie (1900) camped several days in the area that is now known as Copper Center, and he reports on the mosquito populations for that time of the year (June 9-13) as follows:

> "The long expected pests, the mosquitoes, were out in full force, during this day at this camp, and the men were compelled to wear veils day and night with gloves to protect the hands. The ferocity of these mosquitoes is regarded as something remarkable. The species found here is not the large, singing sort seen in the States, but a small, silent, business-like insect, sharp of bill, who touches a tender spot in a surprisingly short time after biting. After making their appearance, they never left the expedition for a day."

Seton (1911) gives an account of his experiences in northern Canada. He reports:

> "Each day they got worse; soon it became clear that mere adjectives could not convey any idea of their terrors. I therefore devised a mosquito gauge. I held up a bare hand for five seconds by the watch, and counted the number of bores on the back; there were five to ten. Each day added to the number, and when we got to the buffalo country, there were fifteen to twenty-five on the one side of the hand and elsewhere in proportion. On the Nyarling in early July, the number was increased, being now twenty to forty. On Great Slave Lake, later that month, there were fifty to sixty. But when we reached the barren grounds, the land of the open breezy plains and the cold-water lakes, the pests were so bad that the hand held up for five seconds aften showed from 100 to 125 long-billed mosquitoes boring away into the flesh. It was possible to number them only by killing them and counting the corpses. What wonder that all men should avoid the open plains, that are the kingdom of such a scourge.

The above account by Seton is the only one known to me in which the numbers of mosquitoes were actually counted. If the mosquitoes in Seton's account were to continue to bite at the same rate, they would total approximately 1,800,000 mosquitoes for a 15 minute period! This is the interval that I used in my studies from 1960 through 1962, which were concerned with the feeding habits of the subarctic and arctic mosquitoes. I never

approached nearly so high a figure as Seton; what I considered intolerable numbers of mosquitoes were encountered at the mouth of the Anaktuvuk River in July of 1962. At this time, we secured 1,253 mosquitoes for this interval of time. Table 28 summarizes the data collected from biting studies, using the abdominal surface of laboratory rabbits and the forearm of a human volunteer.

Table XXVIII. The average number of mosquitoes biting during a 15 minute period. These studies were conducted every 2 hours over a 24 hour period each week throughout the mosquito season. An area of 54 square inches was utilized on each host. The data in this table represent 9,566 biting records.

Host	Average per biting period	
	1960	1961
Forearm (Man)	54.17	69.23
Rabbit	24.11	32.12

The maximum number for one feeding was 350 on man, and 194 on the rabbit. It should be kept in mind, when comparing the mosquitoes on man and the rabbit that the mass of the human body exuding carbon dioxide and heat was far larger than that of the total mass of the rabbit, and is perhaps responsible for some of the difference in the data obtained. A breakdown by species did not reveal any significant shift between these two hosts; in other words, the same species were dominant upon both. In order of abundance, they were, Aedes excrucians, Aedes punctor, Aedes intrudens, and Aedes pionips. These studies did not begin until shortly after the first

of June during 1960 and 1961, and at that time the peak for Culiseta alaskaensis had already passed, and only an occasional specimen of this mosquito was encountered. Several other species were observed more or less routinely, but they did not make up any where nearly so great a proportion of the biting records as any of the four mosquitoes previously mentioned and are not mentioned at this time. Table 29 reviews the results of a study concerned with the vertical stratification of mosquitoes in a white spruce forest near Fairbanks. The hosts used in this study were the standard white laboratory rabbit, varying hares, and domestic chickens. On rare occasions, native gallinaceous birds (willow ptarmigan and ruffed grouse) were utilized. Each type of host was placed in the bait boxes at each level for a twenty-four hour period, at the end of which time the mosquitoes were removed from the bait boxes by means of an aspirator. A period of twelve hours was then allowed to elapse before a different host was placed in the box, and as a control one twenty-four hour period was tested when the boxes were empty. Figure 16 reveals the percentage of mosquitoes attracted to each host in the study of distribution, as tabulated in the previous table.

Figure 17 indicates the percentage of mosquitoes removed from the bait boxes that were actually engorged. It is evident from these tables that the varying hare was more attractive to the mosquitoes than any of the other animals used. One would be led to believe that the domestic chicken was reasonable attractive to

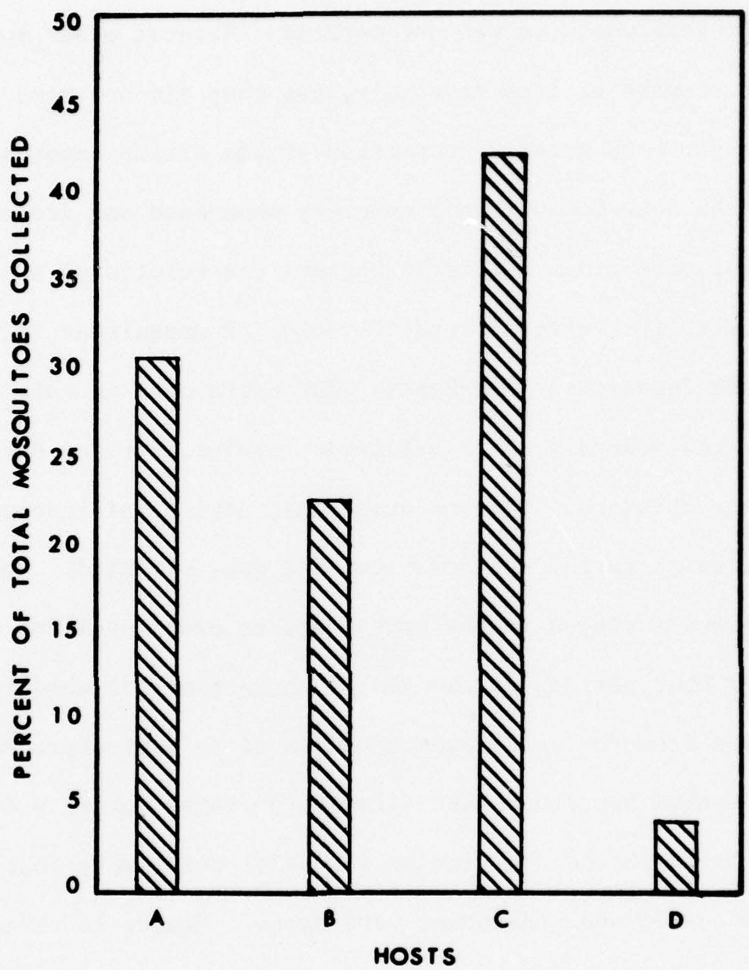


Figure 16. Percentage of mosquitoes attracted to each host in the study of vertical distribution of the mosquitoes. Data for this figure were taken from the preceeding table. A. white rabbit, B. domestic chicken, C. varying hare, D. control (empty bait box).

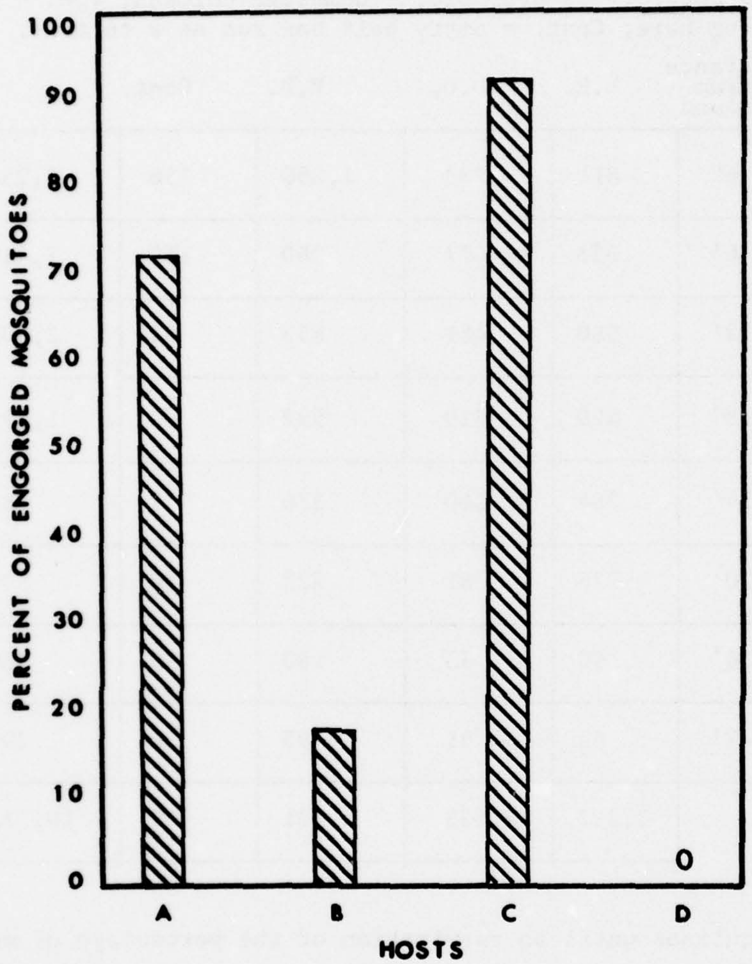


Figure 17. Percentage of captured mosquitoes that were found engorged in the bait boxes with the various hosts. Although the domestic chicken attracted a reasonable number of mosquitoes into the box, very few sought a blood meal. A. white rabbit, B. domestic chicken, C. varying hare, D. control (empty bait box).

Table XXIX. The number of mosquitoes attracted to the various hosts at different levels on the "mosquito tower". L.R. = laboratory rabbit; D.C. = domestic chicken; V.H. = varying hare; Cont. = empty bait box run as a control.

	Distance from ground	L.R.	D.C.	V.H.	Cont.	
Ground	6"	811	733	1,250	156	2,950
p. 1	6'	823	477	960	150	2,410
p. 2	12'	580	481	853	95	2,009
p. 3	18'	420	319	592	60	1,391
p. 4	24'	264	240	370	7	881
p. 5	30'	276	81	223	10	590
p. 6	36'	90	63	180	5	338
p. 7	42'	63	41	93	6	203
		3,327	2,435	4,521	489	10,772

subarctic mosquitoes until an examination of the percentage of mosquitoes that were engorged in the bait boxes is made. This sheds quite a different light on the matter. Only 18.2 percent were engorged, compared to 70 percent for the white laboratory rabbit and 92 percent for the varying hare. These observations are essentially in agreement with the studies carried out by Downe (1960) is his studies in Canada. Downe concluded that the chickens were quite unattractive to the mosquitoes. The small number of results that I obtained with native gallinaceous birds were essentially similar to those of the domestic

chicken.

In an effort to check the mosquito populations adjacent to Nordale Woods, where the vertical study was carried out, professional insect nets were utilized in a sweeping fashion, describing an arc of 180^{o} in front of a collector. This was done also in order that we might gain some idea as to the number of specimens in the area that had had a previous blood meal. Of 46,123 mosquitoes captured in this way, only six were encountered that had had a previous blood meal. In other words, less than one-half of one percent of some forty-odd thousand mosquitoes had had a previous blood meal. The above information is particularly interesting when one reviews the records of Natvig (1948), who recorded various species of mosquitoes attacking nestling birds in Norway. According to Natvig, Aedes punctor was observed feeding on a sparrow hawk, Aedes communis on grouse, and Aedes excrucians and Aedes intrudens on the golden eagle. Natvig also reported the following nestling birds were attacked by unidentified species of mosquitoes: the rough-legged hawk, crow, gull, lapwing, and kestrel.

Thienemann (1939) reported that Aedes punctor and Aedes communis were observed feeding on voles and lemmings. Thienemann indicated that these animals probably constituted the principal source of blood meals for the mosquitoes in the Scandinavian Arctic. Longstaff (1932) has reported Aedes nigripes feeding on the young redpolls, and possibly on the arctic hare, in Greenland. Numerous

observations by me on nestling birds throughout the interior of Alaska have led me to think that these animals do not constitute an important source of blood meals for the subarctic and upland tundra mosquitoes.

With regards to Thienemann's report on the voles and the lemmings, I also feel that this is an untenable concept. The voles and the lemmings are most active during the cooler part of the diel cycle, and possibly the temperature then is below the level at which mosquitoes do most of their biting. Certainly, the voles are moving through the vegetation so rapidly that the mosquito has little or no chance of staying on them long enough to become engorged. Most likely, at least in my observations, the mosquitoes would be brushed off as the rodent passed through the vegetation. On the other hand, I have observed the arctic ground squirrel (shown in the frontispiece) and know that on windless days in the tundra regions (Arctic slope) the mosquitoes can make life literally as unpleasant for this rodent as they can for the human observer! The same observations have been made in the upland tundra in the Hudsonian Biotic Province. If a rodent is important, then probably this one animal constitutes a reasonably good source of food. Among the lagomorphs, the varying hare in the taiga region feeds a large number of mosquitoes. When this hare is abundant, the subarctic mosquitoes have ample opportunity to obtain a blood meal. I have watched at relatively close range these mosquitoes feed on the hare, and with the aid of field glasses have been able to

count as many as 25 mosquitoes in various stages of engorgement on one ear. Frequently, in what would ordinarily be the crepuscular hours in lower latitudes, the varying hares will sit along the side of the road in open areas for varying lengths of time with a swarm of mosquitoes around them. Occasionally, they will brush their ears and nose with their forepaws in an apparent attempt to free themselves from some of the mosquitoes. When the varying hare population is low, then it cannot contribute a significant amount to the feeding ecology of subarctic mosquitoes, and there are as many "lean years" insofar as this mammal is concerned as there are years of abundance.

Within the taiga, certain animals such as the caribou and the moose are found. I have never had an opportunity to observe a sufficient number of these animals to ascertain how important they might be as a source of blood for the mosquitoes. I have observations of one caribou in the Arctic tundra which was literally covered with mosquitoes, but this is an isolated case, and I am not sure how much I can extrapolate from the tundra conditions. However, in conversations with William O. Pruitt, I have gathered that in the tundra for some days after a large herd of caribou have passed through, mosquitoes are virtually absent, and I am led to believe that they contribute a very important source of blood meal at this time. I have had trappers and big game guides tell me that they have seen the moose very distracted by the persistent attacks of mosquitoes, and I can well imagine that this is so.

During earlier years at the Arctic Aeromedical Laboratory, several bears were housed in cages at the River Annex. I know that Aedes communis, Aedes punctor, Aedes excrucians, and Culiseta alaskaensis would feed on these animals with considerable avidity.

Numerous laboratory experiments on the feeding habits of the subarctic mosquitoes have been somewhat disappointing. I have run a large series of tests on white laboratory rats, various species of native voles, and snowshoe hares. I could get many species of Aedes (excrucians is as good an example as any) to feed, and have found individuals would frequently take as many as two blood meals before they would oviposit. I have had some specimens take as high as four blood meals before they perished. However, most of them only took one, and in view of the virtual absence of mosquitoes which had had a previous blood meal being taken in our bait traps or by sweeping vegetation, I am forced to believe that the majority of Alaskan mosquitoes do not obtain more than one blood meal. There is not sufficient time nor space to review the phytophagous feeding habits of mosquitoes in the subarctic; suffice it to say that a large number of mosquitoes do feed upon the nectar of native wild flowers and upon the pollen. It is not known how important this type of feeding is in the maintenance of the mosquito populations.

While the above observations on the feeding habits of subarctic mosquitoes are not as extensive as one might desire, they are nonetheless quite substantial and far more extensive than any studies

that have been carried out in the past, and they lead me to believe that little or no chance exists for the transmission of disease organisms by subarctic mosquitoes. We must keep in mind Olin's concept in regards to the relationship of Aedes cinereus, to the tularemia outbreaks in Sweden. However, my observations during 1960-1962 force me to believe that the Alaskan mosquitoes most often do not attempt to secure more than one blood meal. If they are to be effective in the transmission of disease from one animal to another, it could only be through interrupted feedings. I realize that this type of condition can exist, but one must also acknowledge the fact that such circumstances are indeed fortuitous. This concept nullifies work done by Higby (1943a, 1943b), where he utilized such species as Aedes excrucians in the supposed transmission studies of filarial worms to porcupines and hares. For example, Higby reported that the third stage larvae were found in Aedes excrucians by dissection and therefore felt that they were the vectors of this worm to the hare. I do not deny that Higby saw developmental forms of the worm in the thoracic muscles of the mosquito, but his fallacy was that he did not attempt to have the mosquitoes feed a second time and transmit the organisms to known uninfected animals. It is one thing to get a development of organisms within an insect, and an entirely different matter to get these organisms transmitted to a clean laboratory animal when the insect feeds. From my observations on the feeding habits of Aedes excrucians and other animals, you can manipulate them

Table 30. Pool Data of Alaskan Mosquitoes, Summer, 1964
Elbel-Wright and Eschbaugh-Choy-Fujii teams.

Pool #	Sp(P.)	# Indiv.	Location	Date
EW 1	Culiseta alaskaensis	12	Dot Lake & vicinity (dense, grassy vegetation on shore of small lake and in adjacent swamp; 1 mile radius of Dot Lake Chapel)	4-VII-64
EW 2	Aedes communis-punctor group - Aedes pionips	15		"
EW 3	"	25		"
EW 4	"	20	"	"
EW 5	Aedes pionips-punctor group	25	"	5-VII-64
EW 6	Culiseta alaskaensis	25	"	"
EW 7	"	25	"	"
EW 8	Aedes pionips	25	"	"
EW 9	Aedes communis-punctor group	25	"	"
EW 10	Aedes pionips type	25	"	"
EW 11	Aedes communis-punctor group	25	"	"
EW 12	"	22	"	"
EW 14	Aedes pionips type	25	"	"
EW 15	"	25	"	6-VII-64
EW 16	Aedes fitchii type	17	"	"
EW 17	Aedes pionips type	25	"	"
EW 18	Culiseta alaskaensis	25	"	"
EW 19	Aedes excrucians type	4	"	"
EW 20	Aedes pionips type	25	"	"

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Location	Date
EW 21	Culiseta alaskaensis	40	Dot Lake & vicinity (dense, grassy vegetation on shore of small lake and in adjacent swamp; 1 mile radius of Dot Lake Chapel)	6-VII-64
EW 22	Aedes communis-punctor group	25		"
EW 23	Culiseta alaskaensis	25		"
EW 24	Aedes pionips type	25	"	"
EW 25	Culiseta alaskaensis	25	"	"
EW 26	Aedes pionips type	25	"	"
EW 27	Aedes communis-punctor group	25	"	"
EW 28	Aedes pionips type	25	"	"
EW 29	Simulium-Prosimulium type spp.	9	"	"
EW 30	Aedes pionips type	25	"	"
EW 31	Culiseta alaskaensis	25	"	"
EW 32	Aedes communis-punctor group	25	"	"
EW 33	Aedes pionips type	40	"	"
EW 34	"	25	"	"
EW 35	"	25	"	"
EW 36	"	25	"	"
EW 37	"	25	"	"
EW 38	"	25	"	"
EW 39	Culiseta alaskaensis	25	"	"
EW 40	Aedes communis-punctor group	25	"	"

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Location	Date
EW 41	Aedes excrucians type- Aedes fitchii type	28	Gerstle River, Alaska Hwy. 30 mi. E. Delta Jct. (mixed brush)	7-VII-64
EW 42	Aedes communis-punctor group - Aedes pionips	20	"	"
EW 43	Aedes communis-punctor group	35	Black willow) Black spruce) bog	"
EW 44	"	35	Alaska Hwy. 10 mi. E. Delta Jct.	"
EW 45	"	35	"	"
EW 46	Aedes pionips type	20	"	"
EW 47	Aedes communis-punctor group	35	Mixed wooded area, Tanana River Bend Mile 300= Rich. Hwy. 35 mi. NW Delta Jct.	8-VII-64
EW 48	Aedes pionips type	35	"	"
EW 49	"	35	"	"
EW 50	"	35	"	"
EW 51	"	35	"	"
EW 52	"	35	"	"
EW 53	Aedes communis-punctor group	35	"	"
EW 54	Aedes pionips type	35	Mixed wooded area, Tanana River Bend Mile 300: Rich. Hwy. / 35 mi. NW Delta Jet.	"
EW 55	Aedes communis-punctor group - Aedes pionips	35		"
EW 56	Aedes pionips type	35	"	"
EW 57	Aedes communis-punctor group - Aedes pionips	35	"	"
EW 58	"	35	"	"
EW 59	Aedes pionips type	35	"	"

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Location	Date
EW 60	Aedes communis-punctor group - Aedes pionips	35	Mixed wooded area, Tanana River Bend Mile 300; Rich. Hwy. / 35 mi. NW Delta Jct.	8-VII-64
EW 61	"	40	Aspen-spruce swamp Rich. Hwy. 9 mi. NW Delta Jct.	9-VII-64
EW 62	Aedes communis-punctor group	25	Brush: Lake shore Rich. Hwy. 40 mi. NW Delta Jct.	"
EW 63	Aedes pionips type	37	"	"
EW 64	Aedes communis-punctor group - Aedes pionips	35	Aspen grove & garden area (near stream) Rich. Hwy. 45 mi. NW Delta Jct.	"
EW 65	"	35	"	"
EW 66	"	45	"	"
EW 67	Aedes excrucians type	6	"	"
EW 401	Aedes communis-punctor group - Aedes pionips	40	5 mi. below "Campsites Clear" Old birch-spruce stand.	12-VII-64
EW 402	Simulium-prosimulium type spp.	25	Going North "C.C." + 15 mi. grassland + mixed wood	"
EW 403	Aedes communis-punctor group - Aedes pionips	120	"	"
EW 404	Aedes excrucians type	65	"C.C." + 25 mi. grass-land, swamp, bushes	"
EW 405	Aedes communis-punctor group - Aedes pionips	40	"	"
EW 406	"	125	"C.C." + 35 mi. dense, mixed vegetation + woods	"
EW 407	Aedes excrucians type	35	"	"
EW 408	"	30	"C.C." + 45 mi. high altitude birch + spruce stand	13-VII-64

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Location	Date
EW 409	Aedes communis-punctor group - Aedes pionips	40	"C.C." + 55 mi. poplar, birch & spruce trees with bushes	13-VII-64
EW 410	Aedes excrucians type	100	"C.C." + 65 mi. poplar spruce - on mossy ground	"
EW 411	Aedes communis-punctor group - Aedes pionips	25	"C.C." + 75 mi. poplar, with stony grass stand	"
EW 412	Aedes pionips type	90	Eagle Summit: upland tundra, Steese Hwy. (109 mi. NE Fairbanks)	15-VII-64
EW 413	"	100	Miller House Alaska 114 mi. NE Fairbanks: mixed	"
EW 414	"	100	forest. (Random collecting done within 1 mi.	"
EW 415	"	100	radius of Miller House Post Office.)	"
EW 416	"	100	"	"
EW 417	"	100	"	"
EW 418	"	100	"	"
EW 419	"	55	"	"
EW 421	Aedes communis-punctor group - Aedes pionips	80	Mi. 89, Steese Hwy. grassy, mixed woods	20-VII-64
EW 422	"	70	Mi. 104: "	"
EW 423	"	85	Mi. 119: "	"
EW 424	"	65	Mi. 134: "	"
ECF 1	Aedes punctor group	15	McCollum Creek Mi. 202 Rich. Hwy. Site #1	4-VII-64
ECF 2	"	10	"	"
ECF 3	Red blackfly	1	"	"

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Location	Date
ECF 4	Aedes punctor group	18	McCollum Creek Mi. 202 Rich. Hwy. Site # 1	4-VII-64
ECF 5	Blackfly spp.	7	"	"
ECF 6	Aedes punctor group	15	"	"
ECF 7	Snipe fly	1	"	"
ECF 8	Aedes punctor group	15	"	"
ECF 9	"	15	"	"
ECF 10	"	15	"	"
ECF 11	"	13	"	"
ECF 12	"	23	"	"
ECF 13	"	22	"	"
ECF 14	Red blackfly	1	Mile 205.5 Richardson Hwy. (Site #2)	"
ECF 15	Aedes punctor group	40	(Ecology-beaver pond habitat)	"
ECF 16	"	40	"	"
ECF 17	"	40	"	"
ECF 18	"	40	"	"
ECF 19	"	40	"	"
ECF 20	"	40	"	"
ECF 21	"	40	"	"
ECF 22	"	40	"	"
ECF 23	Red blackfly	3	Black Rapids on Richardson Hwy. From high elevation	"
ECF 24	Aedes punctor group	15	almost above tree line: habitat Ledum palustre,	"
ECF 25	"	15	Empetrum, Salix, Alnus. Mi. 226 (Black Rapids Training	"
ECF 26	"	15	Station) Site #1A, Mile 202, Richardson Hwy. High	"
ECF 27	"	3	Alt. (above treeline) habitat	"
ECF 28	"	30	Salix, Alnus, Ledum, Claytonia	"

Table 30. (Cont.)

Pool #	Sp([illegible].)	# Indiv.	Location	Date
ECF 29	Blackfly	3	Mile 215 Richardson Hwy. Lowland along river	4-VII-64
ECF 30	Aedes punctor group	20	area (Delta River)	"
ECF 31	"	20	"	"
ECF 32	"	20	"	"
ECF 33	"	20	"	"
ECF 34	"	20	"	"
ECF 35	"	40	Mile 236 Richardson Hwy.	"
ECF 36	"	40	"	"
ECF 37	"	40	"	"
ECF 38	Aedes punctor group	40	"	"
ECF 39	Banded-legged Aedes	1	"	"
ECF 40	Culiseta	2	Mile 226 Black Rapids "	"
ECF 41	Aedes ___?___	40	Lowland pond	"
ECF 42	"	40	"	"
ECF 43	"	40	"	"
ECF 44	"	40	"	"
ECF 45	"	40	"	"
ECF 46	"	40	"	"
ECF 47	Banded-legged Aedes Aedes punctor group	1 40	Mile 244 Richardson Hwy. "	6-VII-64 "
ECF 48	"	40	"	"
ECF 49	"	40	"	"
ECF 50	"	40	"	"
ECF 51	"	30	"	"

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Location	Date
ECF 52	Aedes punctor group	50	Mi. 250 Richardson Hwy.	6-VII-64
ECF 53	Banded-legged Aedes	2	"	"
ECF 54	Culiseta alaskaensis	6	"	"
ECF 55	Aedes excrucians	8	Mi. 255 Richardson Hwy.	"
ECF 56	Aedes punctor group	3	"	"
ECF 57	Aedes excrucians	11	"	7-VII-64
ECF 58	Aedes intrudens	9	"	"
ECF 59	Aedes punctor group	50	Clearwater Creek Campsite 8 mi. N. of Mi. 1415 Alaska Highway	"
ECF 60	Culiseta alaskaensis	2	Mile 1415 Alaska Hwy.	"
ECF 61	Aedes excrucians	7	"	"
ECF 62	Aedes punctor group	15	"	"
ECF 63	Aedes excrucians	1	Mile 265 Richardson Hwy.	"
ECF 64	Aedes punctor group	4	Woodland area "	"
ECF 65	Aedes	23	Mile 275 Richardson Hwy.	"
ECF 66	Aedes stimulans	3	Pool habitat	"
ECF 67	Aedes punctor type	25	"	"
ECF 68	"	25	"	"
ECF 69	Culiseta sp.	2	Mi. 300 Richardson Hwy. 23 mi. E. Harding Lake	"
ECF 70	Aedes punctor group	60	Streamside "	"
ECF 71	"	60	"	"
ECF 72	Culiseta alaskaensis	2	Harding Lake: birch, white spruce	8-VII-64
ECF 73	Banded-legged Aedes	5	"	"
ECF 74	Aedes punctor group	40	"	"
ECF 75	"	41	"	"

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Location	Date
ECF 76	*Culex* or *Culiseta*	1	Mi. 331.2 Richardson Hwy.	9-VII-64
ECF 77	*Culiseta alaskaensis*	1	Shaded + dense wooded vegetation	"
ECF 78	Banded-legged Aedes	14	"	"
ECF 79	*Aedes punctor* group	60	"	"
ECF 80	"	60	"	"
ECF 81	Banded-legged *Aedes*	10	"	"
ECF 82	*Culiseta* sp.	1	Mi. 340 opp. Eielson AFB. Richardson Hwy.	"
ECF 83	*Aedes punctor* group	40	"	"
ECF 84	"	46	"	"
ECF 85	Banded-legged *Aedes*	10	Mile 351 Richardson Hwy. 1 mi. W. North Pole	"
ECF 86	*Aedes punctor* group	40	(Pool habitat)	"
ECF 87	Banded-legged *Aedes*	39	Nenana Hwy. (at pt. where it intersects Nenana River)	12-VII-64
ECF 88	*Aedes punctor* group	100	Birch-spruce aspen.	"
ECF 89	*Culiseta* sp.	2	" 30 Mi. S. Nenana	"
ECF 90	*Aedes punctor* group	80	"	"
ECF 91	Banded-legged *Aedes*	2	"	"
ECF 92	*Culiseta* sp.(unbanded)	6	"	"
ECF 93	" (banded)	3	"	"
ECF 94	*Aedes punctor* group	85	"	"
ECF 95	*Culiseta* sp.	1	" 10 Mi. S. Nenana	"
ECF 96	Banded-legged *Aedes*	12	"	"
ECF 97	*Aedes punctor* group	100	"	"
ECF 98	"	45	" Nenana at Ferry Landing	"

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Locality	Date
ECF 99	Banded-legged Aedes	60	Nenana Hwy. at Ferry Landing	12-VII-64
ECF 100	"	47	10 Mi. N. Nenana	"
ECF 101	Culiseta sp.	2	" dense birch-alder stand	"
ECF 102	Aedes punctor group	100	"	"
ECF 103	"	40	"	"
ECF 104	"	58	20 Mi. N. Nenana	13-VII-64
ECF 105	Culiseta sp.	9	20 Mi. N. Nenana + poplars	"
ECF 106	Banded-legged Aedes	75	"	"
ECF 107	Blackfly spp.	14	30 Mi. N. Nenana	"
ECF 108	Aedes punctor group	51	"	"
ECF 109	Banded-legged Aedes	27	"	"
ECF 110	Blackfly	16	" 41 Mi. Nenana at Alder Ck. F.A.A.	"
ECF 111	Aedes punctor group	39	"	"
ECF 112	Banded-legged Aedes	104	"	"
ECF 113	"	21	3 Mi. E. Cripple Cr., 12 Mi. W. Ft. Wainwright A.T.C.	"
ECF 114	Aedes punctor group	88	"	"
ECF 115	Culiseta sp.	5	Circle City, Yukon River (Mi. 162, Steese Hwy.)	14-VII-64
ECF 116	Banded-legged Aedes	11	"	"
ECF 117	Aedes punctor group	100	"	"
ECF 118	Banded-legged Aedes	18	Mi. 147 Steese Hwy. (Birch Creek)	15-VII-64
ECF 119	Aedes punctor group	100	"	"
ECF 120	"	100	"	"

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Location	Date
ECF 121	Aedes punctor group	65	Mi. 132 Steese Hwy. Birch-spruce association	15-VII-64
ECF 122	Banded-legged Aedes	14	"	"
ECF 123	Aedes punctor group	100	"	"
ECF 124	"	100	"	"
ECF 125	"	100	"	"
ECF 126	"	77	"	"
ECF 127	Banded-legged Aedes	11	Mi. 119 Bed Rock campground, Steese Hwy. Spruce + sphagnum habitat	"
ECF 128	Aedes punctor group	100		"
ECF 129	"	100	"	"
ECF 130	"	100	"	"
ECF 131	"	100	"	"
ECF 132	"	50	"	"
ECF 133	Culiseta sp.	5	Mi. 74 Steese Hwy. Spruce-birch alder	"
ECF 134	Aedes punctor	100	"	"
ECF 135	"	100	"	"
ECF 136	"	118	"	"
ECF 137	"	80	Mi. 59 "	16-VII-64
ECF 138	"	60	"	"
ECF 139	"	80	Mi. 44 t. willow	"
ECF 140	Banded-legged Aedes	5	"	"
ECF 141	Aedes punctor group	75	Mi. 29 "	"
ECF 142	"	75	"	"
ECF 143	"	45	Mi. 14 "	"

Table 30. (Cont.)

Pool #	Sp(P.)	# Indiv.	Location	Date
ECF 144	Banded-legged Aedes	3	Mi. 14 t. willow	16-VII-64
ECF 145	"	12	Tanana River a. Manley Hot Springs 163 Mi. W. Fairbanks	18-VII-64
ECF 146	Aedes punctor group	60		"
ECF 147	"	60	"	"
ECF 148	Culiseta sp.	2	Hutlitakwa Creek 23.6 Mi. E. Manley Hot Springs Elliot Hwy.	19-VII-64
ECF 149	Banded-legged Aedes	2		"
ECF 150	Aedes punctor group	100	"	"
ECF 151	"	100	"	"
ECF 152	"	85	"	"
ECF 153	Banded-legged Aedes	6	40.2 Mi. E. Manley Hot Springs	"
ECF 154	Aedes punctor group	85	"	"
ECF 155	Banded-legged Aedes	2	60.4 Mi. E. Manley Hot Springs	"
ECF 156	Aedes punctor group	100	"	"
ECF 157	"	95	80 Mi. E. Manley Hot Springs, Black poplar, willow, alnus	20-VII-64
ECF 158	Banded-legged Aedes	5	60 Mi. N. Fairbanks, Mi. 49, Elliot Hwy.	"
ECF 159	Aedes punctor group	38	41 Mi. spruce, birch "	"
ECF 160	Banded-legged Aedes	11	? 31 mi. N.	"
ECF 161	Aedes punctor group	101	"	"
ECF 162	Banded-legged Aedes	4	21 Mi. Grassy, marsh "	"
ECF 163	Aedes punctor group	70	"	"

in the laboratory and have them obtain a second blood meal, on rare occasions a third, and even rarer, a fourth meal; this seldom if ever occurs in nature.

Table 30 shows the collection of mosquito pools obtained in this study. All of these mosquitoes, constituting 9,788 specimens comprising 254 pools were collected by two teams furnished from Fort Dugway. Dr. Robert E. Elbel was in charge of one group, and their pools are labeled EW. The second team under the direction of Lieutenant Hardy Eschbaugh are labeled ECF.

MICROBIOLOGICAL ASSAY

This phase of the study has been the most difficult to organize and to have all the personnel thoroughly integrated as a team. This, however, has been accomplished and the work now proceeds in a most satisfactory fashion. In this particular area of the study it is difficult, if not impossible, to complete the assays within a specified time limit because of the innumerable complications that can arise. I am not at all certain of the sagacity of such a compact time schedule as we have tried to keep this past year.

Before discussing our current results, it seems appropriate to mention certain of other studies that have been done in Alaska that have an immediate bearing upon this program. The results to be reported are, for the most part, either not available in the literature or are not easy to find.

Hopla (1962) listed the following number of animals that were captured and tissues removed for the possible recovery of tularemia organisms in Central Alaska: arctic ground squirrel (Citellus parryi) 250, red-backed vole (Clethrionomys rutilus) 1,500, tundra vole (Microtus oeconomus) 2,223, red squirrel (Tamiasciurus hudsonicus) 1,500, varying hare (Lepus americanus) 650, muskrat (Ondatra zibethicus) 25, pika (Ochotona collaris) 20, shrew (Sorex sp.) 300, marmot (Marmota caligata) 6. With the exception of one muskrat, all of these animals proved negative for tularemia organisms. The organisms isolated from the muskrat were of relatively low virulence. Utilizing the method of Reed and Muench (1938) an LD_{50} titration in white mice and guinea pigs was $10^{-3.8}$ and $10^{-4.2}$ respectively. This LD_{50} titration compares rather favorably with that reported earlier for the titration made on the positive pool of ticks.

Insofar as I know, the only study that has been done concerning the resistance of Alaskan mammals to tularemia was performed in 1956 by Downs, Hopla, and Metcalf. These data have never been published but because they have considerable bearing on the current problem, I have taken the liberty of summarizing this investigation in the following pages. These studies were not accomplished on a sufficient number of animals to give the broad interpretations desired but I believe they indicate, without question, some interesting relationships between F. tularensis and certain native mammals. The general plan of the experiments was as follows.

All the animals with the exception of the brown lemming (laboratory record), were live-trapped and held for approximately two weeks to determine their ability to survive in captivity and to discover any latent disease. The animals were bled previous to the experimental studies and the serology was negative with the exception of one ground squirrel which had a titre of 1:40. They were divided into suitable groups for innoculation and received serial ten-fold solutions of a standard suspension of a virulent strain of F. tularensis which was known as Sm. The standard suspension contained between two to four billion organisms when matched against a turbidity standard. The number of organisms was always checked by plating on glucose cysteine blood agar plates. All doses were administered intraperitoneally. The animals were observed for two weeks and all animals that died were autopsied. The heart blood (hb), and spleen(s), and at times, liver (l), were cultured on glucose cysteine blood agar plates. A control group always received only saline. At the end of 14 days the surviving animals were bled, if possible, and the serum sent to the University of Kansas for serological tests. The surviving animals were then challenged with one- to one-thousand lethal doses of the Sm strain which was innoculated intraperitoneally.

Animals to be tested for the ability to become resistant after sub-lethal infection were divided into suitable groups and were then injected with measured dose of a strain of lowered virulence (Jap). These animals were observed for 9 to 14 days,

autopsied when necessary, and bled. After bleeding, they were then challenged with 100 to 1000 lethal doses of the virulent Sm strain. The results of the tests are given in tables 31, 32, and 33. Table 31 shows the results of injections of the Sm strain into 16 hares. They received from 2 to 1906 organisms and 4 hares were held as controls. Four animals out of 16 died but since no organisms were recovered in autopsy these were considered non-specific deaths. In a second test (Table 32), 16 hares received from 26 to 26 million organisms. Four of those hares which received the largest doses died, one after receiving 260 thousand organisms and one died a non-specific death after 26 organisms. It may be seen from Tables 31 and 32 that 1905 to 2600 organisms constituted a sub-lethal dose and the lethal dose lay between 260 thousand and 26 million organisms. This would indicate a high degree of resistance to tularemia organisms by the varying hare. In evaluating the immunity to challenge, 19 hares which had survived from 1900 to 260 thousand organisms were challenged with 112 to 85 million organisms approximaely 2 weeks after the first infection. Four died a non-specific death, 3 died specific deaths out of the remaining 12 thus giving a death rate of 25 percent. Of the 6 animals that had received no organisms prior to challenge, 3 survived and 3 died. It is hazardous to base any estimation of the degree of immunity arising from prior infection in such a small number of test and control animals, particularly when dealing with such a highly resistant animal as

TABLE 31

DETERMINATION OF THE LD_{50} IN LEPUS AMERICANUS FOLLOWED BY CHALLENGE OF SURVIVORS. THE HARES USED FOR THESE DATA WERE COLLECTED NEAR FAIRBANKS AND BIG DELTA ENVIRONS.

Rabbit Number	Infection Number and Strain	Day of Death	Dead/Tested	Culture at Death	26 days after Infection Before Challenge		Results of Challenge			
					Agg.	HA	Date and Strain	Day of Death	Dead/Tested	Culture at Death
				S,L,Hb-			26 days			
61	Intra-	4								
62	peritoneal	S			1-640	1-2560	Sm	3		Negative
63	1 ml Sm	S			1-640	1-2560	113×10^6	S		
64	1905	4	2/4	S,L,Hb-			IP		1/2	
71	180	S			320	640	26 days	8		Hb, S-
72	180	S			640	1280	Sm	S		
73	180	S			160	320	113×10^6	S		
74	180	S	0/4		320	?1-20	IP	S	1/4	
81	18-19	Trauma					26 days			
82	18-19	S			640	1280	Sm	9		Hb, S+
83	18-19	S			320	2560	113×10^6	5		Hb, S+
84	18-19	S	0/4		320	2560	IP	3	3/3	Hb, S+
91	1-2	4		S,L,Hb-			26 days			
92	1-2	S			640	20	Sm	S		
93	1-2	S			640	2560	113×10^6	2		Hb, S-
94	1-2	4	2/4	S,L-			IP		1/2	
Controls										
1	0	4		S,L-	-	-	26 days			
2	0	S			-	-	Sm	S		
3	0	S			-	-	113×10^6	4		Hb, S+
4	0	S	1/4		-	-	IP	7	2/3	Hb+

TABLE 32

DETERMINATION OF THE LD_{50} TITRE IN LEPUS AMERICANUS FOLLOWED BY CHALLENGE OF SURVIVORS. THE HARES USED FOR THESE DATA WERE COLLECTED ALONG THE NOATOK RIVER.

Rabbit Number	Infection Number and Strain	Day of Death	Dead/Tested	Culture at Death	Before Challenge		Result of Challenge			
					Agg.	HA	Date and Strain	Day of Death	Dead/Tested	Culture at Death
21	$26x10^6$	2		S, Hb+			16 days after			
22	Intra-	4		S, Hb+			initial infec-			
23	peritoneal	3		S, Hb+			tion Sm IP			
24	Sm 1 ml	3	4/4	S, Hb+			$85x10^6$			
							1 ml			
41	$26x10^4$	S			80	320	16 days after	S		
42		S			1280	1280	initial infec-	S		
43		6		S, Hb+			tion Sm IP			
44		S	1/4		1280	320	$85x10^6$	S	0/3	
							1 ml			
61	26×10^2	S			1280	1280	16 days after	4		S, Hb-
62		S			320	320	initial infec-	8		S, Hb-
63		S			640	520	tion Sm IP	S		
64		S	0/4		640	40	$85x10^6$	S	2/4	
							1 ml			
81	26	S			640	80	16 days after	S		
82		S			-	-	initial infec-	S		
83		S			-	-	tion Sm IP	S		
84		9	1/4	S, Hb-			$85x10^6$		0/3	
							1 ml			
Controls										
1	0	S			-	-	16 days after	7		S, Hb+
2	salt	S			-	-	inital infec-	S		
3	solution	S			-	-	tion Sm IP	S		
4	only	11	1/4	S, Hb-			$85x10^6$		1/3	
							1 ml			

a varying hare seems to be.

Table 33 gives the data of the results of immunization of 6 hares with the living Jap strain 237 x 10^4. Six other hares (controls) received diluent only. Five out of the 6 immunized developed relatively low antibody titres ranging from 1:20 to 1:80. The hemagglutination test usually reacted in one dilution tube higher than the standard bacterial agglutination test. After challenge with 200 million organisms of the virulent Sm strain, one out of three died. All of the controls died. It is doubtful if one can contribute the survival of the two remaining hares to prior immunization. For example, Table 32 shows that although 26 million organisms killed 4 out of 4 normal animals, in the test shown in Table 33, *twenty million organisms killed none out of three!*

In animals such as the varying hare which have a high level of resistance, large numbers of animals are necessary before proper conclusions can be drawn. In a natural population, individual tolerance to disease organisms is a highly variable thing. Such investigations have not been nearly as thoroughly explored in this respect as is needed.

Arctic Ground Squirrel: It was possible to perform two LD_{50} determinations on the arctic ground squirrels using four animals per level. These results are shown in Tables 34 and 35. In the first experiment the LD_{50} was less than 10^{-9}; in the second experiment

TABLE 33

IMMUNIZATION OF *LEPUS AMERICANUS* WITH LIVING CULTURES OF A STRAIN OF LOW VIRULENCE FOLLOWED BY CHALLENGE WITH A VIRULENT STRAIN.

Rabbit Number	Infection Number and Strain	Before Challenge		Result of Challenge			
		Agg.	HA	Date and Strain	Day of Death	Dead/Tested	Culture at Death
1 2 3	1 ml Intra-peritoneal (Jap) 237×10^4	40 20 -	80 40 -	0.5 ml Intra-peritoneal 2×10^8 Sm 9 days after initial infect.	9 S S	1/3	No record
Controls 4 5 6	Diluent only	- - -	- - -	0.5 ml Intra-peritoneal 2×10^8 Sm 9 days after initial infect.	2 5 3	3/3	Hb + Hb + Hb +
7 8 9	1 ml Intra-peritoneal (Jap) 237×10^4	20 40 40	40 80 80	As above but with 2×10^7 Sm	S S S	0/3	
Controls 10 11 12	Diluent only	- - -	- - -	As above but with 2×10^7 Sm	S S S	0/3	

TABLE 34

DETERMINATION OF THE LD_{50} IN CITELLUS PARRYI FOLLOWED BY CHALLENGE OF SURVIVORS. THESE ANIMALS WERE COLLECTED BETWEEN BIG DELTA AND BLACK RAPIDS.

Ground Squirrel Number	Infection Number and Strain	Day of Death	Dead/Tested	Culture at Death	Before Challenge		Result of Challenge			
					Agg.	HA	Date and Strain	Day of Death	Dead/Tested	Culture at Death
61	0.5ml Intra-peritoneal Sm 1905	5		S[1], Hb[3]+			113×10^6 16 days after initial infection 0.5 ml Sm IP			
62		6		S, Hb+						
63		7		S, Hb+						
64		7	4/4	S, Hb+						
71	180-190	8		S, Hb+						
72		8		S, Hb+						
73		4		S, Hb+						
74		5	4/4	S, Hb+						
81	18-19	7		S, Hb+						
82		7		S, Hb+						
83		5		S, Hb+						
84		7	4/4	S, Hb+						
91	1-2	5		S, Hb+			Same as above			
92		8		S, Hb+						
93		6		S, Hb+	-					
94		S	3/4					8	1/1	S, Hb+
1	0	S			-	-	Same as above	2		S, Hb+
2		S			-	-		9		S, Hb+
3		S			-	-		2		S, Hb+
4		S	0/4		-	-		7	4/4	S, Hb+

TABLE 35

DETERMINATION OF THE LD_{50} TITRE IN CITELLUS PARRYI FOLLOWED BY CHALLENGE OF SURVIVORS. THE ANIMALS WERE COLLECTED BETWEEN BIG DELTA AND BLACK RAPIDS.

Ground Squirrel Number	Infection Number and Strain	Day of Death	Dead/Tested	Culture at Death	Before Challenge		Results of Challenge			
					Agg.	HA	Date and Strain	Day of Death	Dead/Tested	Culture at Death
81	Sm 0.5 ml	9		Hb+			86			
82	Intra-	7		Hb+			0.5 ml IP			
83	peritoneal	7		Hb+			16 days			
84	26-28	5	4/4	S, Hb+			after initial infection			
91	2-3	1-11		Hb+						
92		11		Hb+						
93		11		Hb+						
94		7	4/4	Hb, S+						
101		S			-	-	Same as	9		No record
102		S			-	-	above	7		S+
103		S			-	-		8		S, Hb+
104		7	1/4	Hb+					3/3	
Controls					-	-		8		
1	0	S			-	-	Same as	7		
2		S			-	-	above	8		
3		S			0	0		No record	3/3	
4		S	0/4							

it was $10^{-9.6}$. F. tularensis was recovered from all animals that died. The controls and those receiving less than one organism in the 10^{-10} dilution were challenged with 86 organisms of the Sm strain. All died specific deaths except one animal from which no organisms were received. Ground squirrels are thus as susceptible to tularemia organisms as domestic rabbits, guinea pigs, and white mice.

Table 36 gives the results of an immunizing infection of ground squirrels with approximately 237 organisms of the Jap strain. Three animals showed agglutinins at the end of nine days. Two animals survived challenge with 100 organisms of the virulent strain and 2 animals survived 10 organisms. Since all controls died, this probably indicates that the squirrels had acquired some immunity as a result of their prior infection with Jap. These results compare favorably with those obtained by Downs in her extensive investigation on white mice.

Red-backed Voles: It was possible to determine an LD_{50} on one group of 16 red-backed voles. The dilutions ranged from 10^{-7} to 10^{-10} as shown in Table 37. The LD_{50} of $10^{-9.3}$ indicated they were as susceptible as white mice and guinea pigs. The one which survived and the four control mice which had received diluent only succumbed to specific infection when challenged with 40 organisms of the Sm strain.

TABLE 36

IMMUNIZATION OF <u>CITELLUS PARRYI</u> WITH LIVING CULTURES OF A STRAIN OF LOW VIRULENCE FOLLOWED BY CHALLENGE WITH A VIRULENT STRAIN.

Ground Squirrel Number	Infection Number and Strain	Before Challenge		Results of Challenge			
		Agg.	HA	Date and Strain	Day of Death	Dead / Tested	Culture at Death
1	1ml Intra-peritoneal (Jap) 237-243	40	-	Sm 0.5ml Intraperitoneal 100 9 days after initial infection	9		S[1] +
2		20	20		S		
3		-	-		S	1/3	
Controls							
1	Diluent only	-	-	Same as above	5		S +
2		-	-		9		S +
3		-	-		8	3/3	S +
1	237-243	-	-	Sm as above but 10 organisms	S		No record
2		-	-		10		
3		80	-		S S	1/4	
Controls							
1	Diluent only	-	-	Same as above	8		S +
2		-	-		8		S +
3		-	-		7	3/3	S +

TABLE 37

DETERMINATION OF THE LD_{50} FOR CLETHRIONOMYS RUTILUS FOLLOWED BY CHALLENGE OF SURVIVORS. THESE VOLES WERE TRAPPED AT FORT WAINWRIGHT (LADD AIR FORCE BASE)

Mice Number	Infection Number and Strain	Day of Death	Culture at Death	Dead/Tested	Results of Challenge: Date and Strain	Results of Challenge: Day of Death	Results of Challenge: Dead/Tested	Results of Challenge: Culture at Death
71	0.5 ml Sm	3	S, Hb+		14 days after			
72	Intraperi-	3	S, Hb+		initial in-			
73	toneal	4	S, Hb+		fection Sm			
74	197-212	3	S, Hb+	4/4	0.5 ml 40			
81	19-22	3	Hb+					
82		4	Hb+		Same as			
83		6	Hb+		above			
84		S		3/4		4	1/1	Hb+
91	1-3	4	Hb+					
92		4	Hb+					
93		5	Hb+					
94		Killed		3/3				
101	0-1	4	S, Hb-					
102		Escaped						
103		2	Hb-					
104		Escaped		2/2				
Controls								
1	0	S			Same as	4		Hb+
2		S			above	4		Hb+
3		S				5		S+
4		S		0/4		5	4/4	S+

TABLE 38
DETERMINATION OF THE LD_{50} IN LEMMUS LEMMUS FOLLOWED BY CHALLENGE OF SURVIVORS. ANIMALS FURNISHED BY DR. R. RAUSCH, ANCHORAGE.

Lemming Number	Infection Number and Strain	Day of Death	Dead/Tested	Culture at Death	Results of Challenge: Date and Strain	Results of Challenge: Day of Death	Results of Challenge: Dead/Tested	Results of Challenge: Culture at Death
61	0.5 ml Sm	3		Hb+	14 days after in-			
62	Intraperi-	3		S, Hb+	itial infection			
63	toneal	3		Hb+	0.5 ml Sm			
64	2600-2800	3	4/4	S, Hb+	223			
71	260-280	4		Hb+				
72		4		Hb+				
73		4		Hb+				
74		4	4/4	Hb+				
81	26-28	4		S, Hb+				
82		5		Hb+				
83		3		S, Hb+				
84		1	4/4	0				
91	2-3	3		Hb-				
92		3		S, Hb+				
93		4		Hb+				
94		6	4/4	Hb+				
Controls								
1	0	S			Same as	4		Hb+
2		S			above	3		Hb+
3		S				4		Hb+
4		1	1/4	Non specific			3/3	

<u>Brown Lemmings</u>: Sixteen lemmings were inoculated with dilutions of 10^{-6} and 10^{-9} as shown in Table 38. All died and *F. tularensis* was isolated from 14 of the animals. One was not tested and no organisms were recovered from it. Three controls which had received diluent only were challenged with 223 organisms of the Sm strain; they all died specific deaths. Again, the susceptibility of lemmings is comparable to that of the white mouse and the guinea pig.

LABORATORY PROCEDURES AND RESULTS: The laboratory techniques employed in this phase of the study are essentially those developed by the personnel at the Rocky Mountain Laboratory and elsewhere. This is especially true when dealing with *Coxiella burnetii* and its antibodies. While I have had considerable experience with *Francisella tularensis* over the years, my experience with Q fever organisms has been modest. Laboratory personnel, although competent in various serological techniques with a wide variety of organisms, had to be trained for the specific problem at hand. This, added to the length of time utilized in obtaining the required security clearances for the technicians, delayed this phase of our research. Actual work on the specimens was started in early October when the clearances were completed.

Serology: <u>Q Fever</u>: The complement fixation test as carried out by us is similar to the method of Welsh (1959). It consists of overnight incubation at 2 to 4^{o} C. of the combined serum, antigen,

and complement, followed by 30 minutes at 37° C. in a water bath after the addition of sensitized sheep cells. Two whole units of complement, two units of antigen, and two units of hemoglobin are then added. A 50 percent visual hemolytic end point is used; proper controls are run with each test. The antigen, Q II 795, is one of the broadest-spectrum phase II antigens known; Ohio 314 phase I antigen is on hand for use where needed. The capillary agglutination test (CAT) has been used as a supplementary test to complement fixation and is thought to be more reliable in testing sera from _Clethrionomys_ and _Microtus_ sera. Microtine rodents are generally regarded as weak producers of complement fixing antibodies. In addition the CAT is particularly useful when working with small amounts of sera as frequently as can be the case in working with small rodents. We produce our own antigen for the CAT from the Ohio 314 strain and in addition have obtained antigen from the Zoonosis Investigation Unit, Communicable Disease Center. The seed stock of the various strains of Q fever organisms mentioned above were furnished by Dr. David Lackman, Rocky Mountain Laboratory.

Tularemia: The standard tube agglutination test, utilizing an avirulent strain (Jap) of _F. tularensis_ as a source of antigen is employed. In previous years I have employed the hemagglutination test but feel the simplicity of the standard agglutination test outweighs what slight advantage in sensitivity (if indeed this is so) the former test may have. In performing the test we incubate

Figure 18. A. Bleeding a passerine bird which has been removed alive from a mist nest.

B. Close up of bleeding technique. We found it simpler to remove blood from a neck vein rather then via cardiac puncture. Frequently, 2cc and up to 3cc of blood were taken from birds such as the white crowned sparrow.

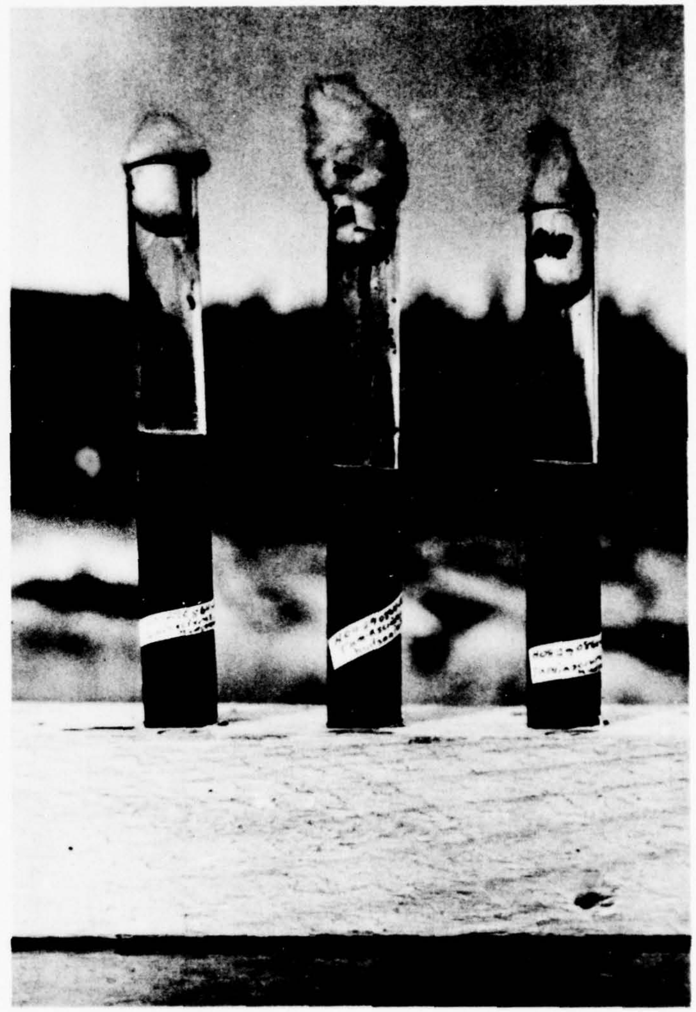
A

B

Figure 19. A. Dairy herds in the Fairbanks region were sampled for antibody surveys by securing 10 cc of blood from the jugular vein. We learned that most dairy animals in Alaska were only "semidomesticated". The person securing the sample blocked the vein with the left hand below the site of the venipuncture.

B. Clot retraction in blood samples obtained from the red squirrel (*Tamiasciurus hudsonicus*) after storage against the permafrost for 7-8 hours. Such storage produced uniformly good serum samples.

A



B

for two hours at 37° C. in a water bath, followed by overnight refrigeration between 2° - 4° C. Positive tests are always rechecked with our own antigen and against Lederle tube antigen. The seed stock for this strain of F. tularensis was supplied by Dr. Cora Owen of the Rocky Mountain Laboratory. The advantages of using an avirulent strain are considerable and it has been my experience and that of other investigators that this strain is fully as antigenic as the more virulent strains.

All sera (both organisms) tentatively identified as positive are rechecked to insure that the results can be repeated. A titre of 1:80 is significant when testing for tularemia antibodies and 1:32 when testing for Q fever antibodies by complement fixation.

In addition to the specific organisms with which we are working, sera were checked for antibodies against Rocky Mountain Spotted Fever, Psittacosis, and Brucellosis. The checks for Rocky Mountain Spotted Fever and Psittacosis have been discontinued because of time limitations.

Isolation of organisms: Figure 21 succinctly summarizes the procedures in this phase of the study.

A source of fertile, antibiotic-free hen's eggs was located a distance of only 3 miles from the university campus. These eggs are incubated for 5 days at a temperature of 99.7°F. before being

used for experimental purposes. Original sources of guinea pigs proved unsatisfactory because they were found to possess antibodies for psittacosis. Our present source of supply, National Animal Laboratories, St. Louis, has proved entirely satisfactory.

Male guinea pigs weighing 250-500 grams are the animal of choice for the routine isolation of the two organisms. The tissues are homogenized in teflon grinders using 5 ml of sterile skim milk as a diluent; 0.5 ml of the resultant suspension is injected intraperitoneally into each of two guinea pigs. All guinea pigs are bled prior to innoculation and the serum is frozen to be checked in the event a valid rise in temperature occurs and antibodies or organisms are observed from the animal. A 1:10 dilution of this homogenate is made and 0.5 ml injected into each of 10 eggs incubated for 5 days at 99.7° F. The remainder of the suspension is sealed in ampules and stored at -60° C. Mosquitoes and other arthropods are handled essentially the same way as the tissue samples except the mosquitoes which are rinsed in two changes of sterile skim milk to free them of the buffered glycerine solution. The ticks and fleas are rinsed in 5% phenol followed by sterile distilled water in an attempt to free them of external contaminents. One thousand units of penicillin are added to the skim milk diluent at the time of grinding.

Rectal temperatures of the guinea pigs are measured daily for three weeks. If readings of 40° C. or above are encountered for

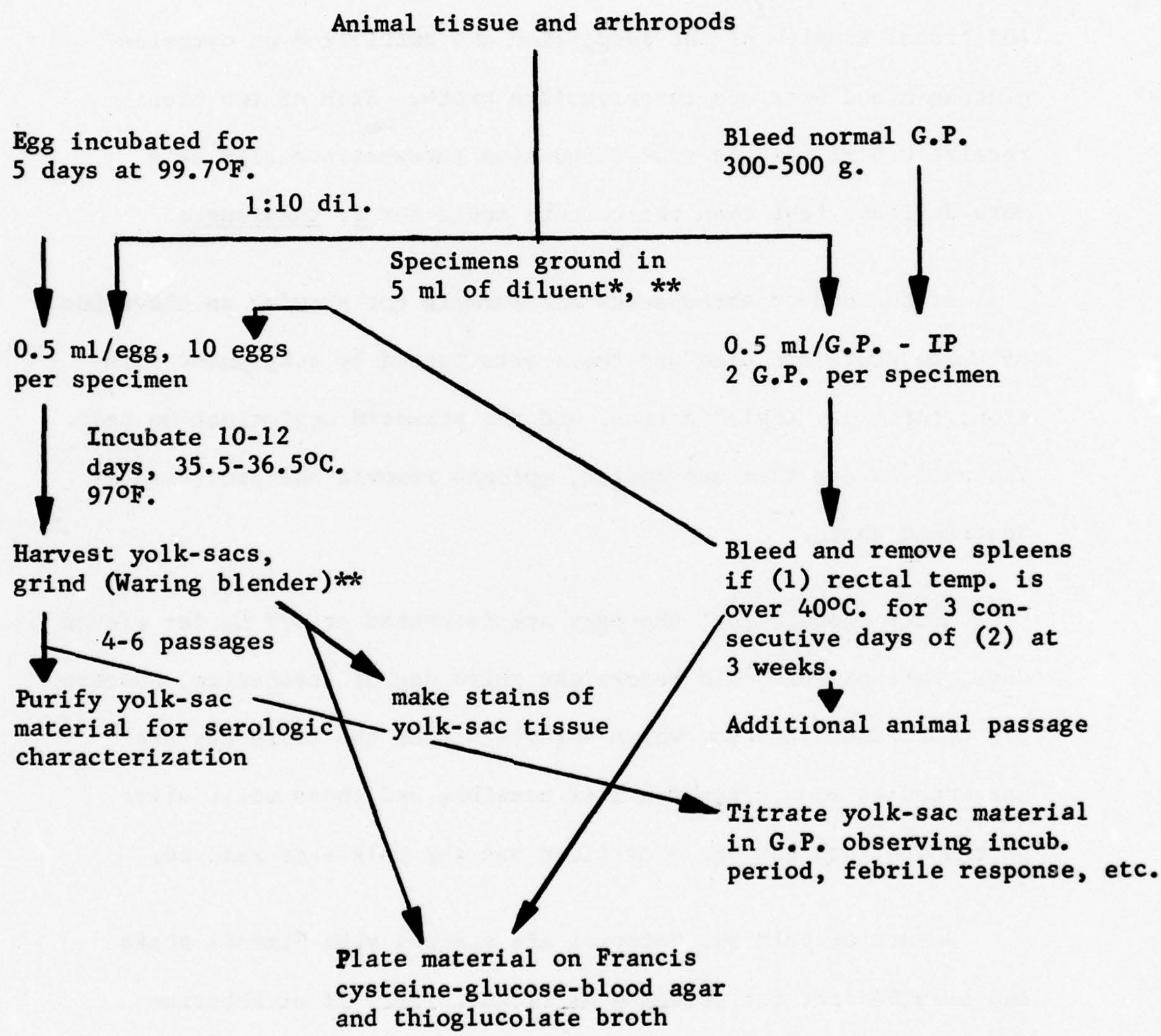
Figure 20. A. Securing tissue samples from Alaskan mammals. Standard procedures were utilized. All tissue tubes were autoclaved before use and sealed in the field with a small acetylene torch. After cooling, the specimens were then stored in liquid nitrogen chests. Tissues from as many as 5 individuals of the same species were pooled.

B. Harvesting serum after clot retraction. Sera from the same species of animal from the same habitat were pooled and stored in the same manner as the tissues.

A

B

Figure 21. Schematic representation of the procedure used for isolation of C. burnetii and F. tularensis.



* Diluent - 10% skim milk (Difco) in phosphate buffered saline pH 7.65

** Freeze aliquots for further study

three days the animals are bled, and transfers of the blood are made to embryonated hen's eggs. Such animals are then sacrificed and the spleens removed. Their spleens are homogenized in the grinders as previously described and injected into embryonated eggs. Additional samples of the suspension are cultivated on cysteine-glucose-blood agar and thioglycolate broth. Each of two mice receive 0.5 ml of this same suspension intraperitoneally as a more delicate test than the culture media for F. tularensis.

At the end of three weeks all animals not showing an elevation of temperature are bled and their sera tested by complement fixation, capillary agglutination, and the standard agglutination test. The animals are then necropsied, spleens removed and processed as described above.

After inoculation, the eggs are incubated at 97° C. for eleven days; embryos which die before the third day of incubation, however, are discarded. Embryos which survive beyond the third day are harvested as soon after death as possible and those still alive on the eleventh day are sacrificed and the yolk sacs removed.

Smears of yolk sac material are stained with Gimenez stain and examined for the presence of rickettsiae. If rickettsiae are found, the yolk sacs are pooled, and the egg passages continued in an attempt to obtain a rich growth of organisms. If a satisfactory yield has been obtained, the yolk sacs from the last passage are harvested and ether-extracted to purify the rickettsiae so

that the organisms can be used as an antigen for serological characterization by complement fixation (Stoenner *et al.*, 1962).

Biologic properties of the isolates of *C. burnetii* are determined by the following methods: Pathogenicity is established by comparing incubation periods and febrile responses in guinea pigs that have been inoculated with 1 ml of the 10^{-5} dilution of yolk sac material of each isolate. Six guinea pigs per isolate are used. Infectivity for Swiss white mice (National Animal Strain) and guinea pigs is determined by titration of yolk sac material from which serial ten-fold dilutions of the yolk sac material are prepared in sterile skim milk solution with 6 white mice and 4 guinea pigs receiving 0.2 ml and 1.0 ml respectively at each dilution. Infectivity end-points are determined in all animals by obtaining blood intracardially 21 days after inoculation and the resultant sera tested for antibodies by complement fixation and capillary agglutinations tests.

All bacteria isolated are identified on the basis of morphological and biochemical characteristics. Bacteria having the colony morphology of *F. tularensis* are stained by Gram's method and examined for organisms which are gram negative and have a morphology similar to tularemia organisms. If organisms fulfull these criteria, slide agglutinations are carried out with known positive antisera.

Upon the completion of the identification of an organism such as *F. tularensis*, its virulence and glycerol fermentation capacity

are tested as described by Owen _et al._ (1964). Virulence capacities of the isolates are compared with such strains as Schu, B259C no. 4, and Jap which are of high, moderate, and low virulence respectively.

Adequate controls are maintained to detect laboratory errors which might arise. In the serological procedures positive and negative control sera are introduced at random and without the knowledge of the persons conducting the test. Animal controls consist of animals injected with only the diluent. Egg controls are essentially similar to those of the animals.

The following tables summarize the work that has been accomplished thus far.

As seen in Tables 39 and 40, low titres against a variety of Alaskan animals were encountered. In all instances where sufficient serum was available for a recheck, confirmatory results were obtained.

As seen in Table 39, 19 of 173 dairy cows are recorded as having antibodies against _C. burnetii_. This is approximately 11 percent of the animals tested. Sera with a titre less than 1:32 were not listed because I consider them of dubious value. Had they been included as positive results the percent of dairy cattle that showed past experience with _C. burnetii_ would be approximately 21 percent. These results are compatible with those of Philip as

Table 39. Positive sera obtained from dairy cattle in the Tanana Valley. A total of 173 animals were tested (AC = anti-complementary).

Dairy	Lab No.	*C. burnetii* CF	*C. burnetii* CAT	*F. tularensis*	*B. abortus*
Golden Heart	10	64	+	-	-
" "	11	64	+	-	-
" "	16	AC	+	-	-
" "	38	256	+	-	-
" "	40	128	+	-	-
" "	41	128	+	-	-
" "	22	32	+	-	20
Creamers	101	64	+		
"	109	32	-		
"	113	128	+		20
"	138	AC	+	80	-
"	144	64			20
"	161	32	+	80	
"	169	256	+	-	-
"	179	32	+	-	-
University	58	64	+		
"	59	128	-	-	80
"	63	AC	+	-	-
"	85	128	-	-	-

Table 40. Positive sera from Alaskan animals other than domestic cattle. The titres are listed under the respective diseases. For the total number of each species taken see Table 2.

Species	Lab No.	*C. burnetii* CF	*C. burnetii* CAT	*F. tularensis*	*B. abortus*
MAMMALS: *Citellus parryi*	237	32	+	-	-
" "	289	-	-	20	-
Tamiasciurus hudsonicus	25	32	-	-	-
"	213	-	-	20	40
"	238	-	-	40	-
"	239	-	-	40	-
"	242	-	-	40	-
"	293	-	-	80	-
"	297	-	-	160	-
"	299	-	-	80	-
"	302	-	-	80	-
"	311	-	-	80	-
Clethrionomys rutilus	205	-	-	40	-
"	340	-	-	40	-
Microtus pennsylvanicus	318	64	-	-	-

Table 40 (continued)

Species	Lab No.	*C. burnetii* CF	CAT	*F. tularensis*	*B. abortus*
Microtus oeconomus	210	-	-	40	-
"	225	-	-	20	-
"	253	640	+	20	-
"	271	-	-	80	-
"	274	-	-	40	-
"	277	-	-	40	-
"	278	-	-	40	-
"	282	-	-	40	-
"	283	-	-	80	-
"	284	-	-	160	-
"	330	-	-	80	-
Erethizon dorsatum	307	-	-	40	-
Lepus americanus	8	64	-	-	-
" "	43	32	-	-	-
" "	53	-	-	-	20
" "	197	-	-	20	-

Table 40. (continued)

Species	Lab. No.	C. burnetii CF	C. burnetii CAT	F. tularensis	B. abortus
Lepus americanus	241	-	-	20	-
" "	244	-	-	20	-
Rangifer tarandus	89	32	-	-	-
" "	121	32	-	-	-
" "	212	64	+	-	-
AVES: Petrochelidon pyrrhonata	217	-	-	80	-
Riparia riparia	255	-	-	320	-
Acanthis flammea	336	-	-	40	-
Ixoreus naevius	361	-	-	80	-
Sciurus noveboracensis	284	-	-	160	-
Spizella arborea	331	-	-	160	-
Lagopus lagopus	246	-	-	20	-

reported by Jellison (1965).

It was interesting to us that one ofthe dairymen was apprehensive about our bleeding his cows. No doubt, this was, in part, produced

because we did not tell him specifically what tests would beutilized, but he did say "The only thing I can think of is Q Fever." inasmuch as his last name is identical with that of the owner of the herd tested by Philip, I have wondered if they are one one and the same individual. All dairymen cooperated fully nonetheless.

From our results and those of Philip it appears evident that Q fever does exist in the various dairy herds within Alaska, not merely within the Tanana Valley. The antibody data are campatible with that reported by several other investigators in other areas of the United States.

As shown in Table 40, some wild mammals and birds produced low antibody titres against C. burnetii and F. tularensis. At this writing, I am not certain as to just what interpretation can be placed upon the nine sera indicated as positive for C. burnetii. The titre of 1:640 for the tundra vole is a surprising result. Other than for this vole, these data are similar to those of Vest et al. (1965). Many more data are needed, however, before we have a proper understanding of the endemcity of this particular organism in Alaska. This is especially true of the three positives listed for caribou. Where possible, I would like to have the serological results from the caribou confirmed by the RIPT method as employed by Dr. David Lackman. I think it particularly important in this instance because thesera are "hunter-collected" and do not lend themselves well to the usual

serological techniques. For example the blood samples are anywhere from one day to several days old by the time they are brought into the collecting station. Frequently they are so hemolyzed they are unusuable. The RIPT technique would largely overcome these difficulties.

The antibody titres against F. tularensis are not unusual, but I am not at all sure what they mean. The varying hare has frequently been found with such low titres, and in the work by Downs et al. (1956) reviewed in the preceeding pages, 1:80 was the highest titre produced. Among captured ground squirrels a titre of 1:40 has been encountered occasionally but upon challenge these antibodies were not protective against a measured quantity of tularemia organisms. Considerable work needs to be done on wild mammals from this standpoint. Most previous studies that dealt with zoonoses have been so busy screening large numbers of animals that time, and frequently facilities, have not permitted other equally important aspects of the study to be undertaken. A large proportion of the laboratory work with tularemia organisms has been confined to such animals as the white mouse, white rabbit, cavies, and white rat. It is uncertain how these findings can be extrapolated to native wild animals.

The low titres found in the microtine rodents were not anticipated because these mammals appear to be as susceptible as

the white mouse, on the basis of the few studies that have been done. These findings agree with unpublished data I have accumulated in the past and with those of Vest *et al*. (1965).

The results on the avian sera have all been negative for *C. burnetii*, which does not agree with Bosova *et al*. (1960). I anticipated we would encounter low titres for *F. tularensis* in members of the family Tetraonidae and I had hoped that we would be able to secure a larger sample of these birds. This was my first experience with passerine birds in a tularemia survey, but since some of them were occasionally infested with the immature stages of *Haemaphysalis leporis-palustris*, relatively high titres might be reasonable. I was not prepared for the higher titres in the bank swallow (*Riparia riparia*) but the results were verified. Further studies with these birds is indicated.

Table 41 presents the data on the attempts to isolate the two organisms from the pools of mosquitoes. The second-passaged materials failed to produce antibody response in the guinea pigs nor was pathology evident in the animals at autopsy. No organisms of either etiological agent have been isolated from first- or second-passaged animal tissues. These tissues are now in third passage. As soon as time permits, these data will be rechecked in their entirety.

Table 41. Antibody titres from mosquito pools passed through first animals. Total of 254 mosquito pools were injected into experimental animals.*

Species	Lab No.	C. burnetii CF	C. burnetii CAT	F. tularensis	B. abortus
Aedes punctor	119	-	-	40	-
Aedes communis	118	-	-	40	-
Aedes punctor	150	-	-	40	-
Aedes punctor	130	-	-	40	-
Aedes excrucians	131	-	-	40	-
Aedes excrucians	133	-	-	40	-
Aedes excrucians	156	32	-	-	-
Aedes pionips	182	-	-	40	-

* All sera tested from the second animal passage were negative. Third passage is now underway.

Tables 42 and 43 show the antibody titres for the first- and second-passed Alaskan tissues. We have not, as yet, been able to isolate either C. burnetii or F. tularensis organisms. We have found rickettsiae-like organisms, in some of the animals injected with vole tissues without production of specific antibody titres. These organisms have not adapted to hens eggs, however, and we are of the opinion that they belong to the group known as "vole rickettsiae" which do not produce disease. I am reasonably certain that they

Table 42. Antibody titres from Alaskan animal tissues passed through first animals.

Species	Lab No.	*C. burnetii* CF	*C. burnetii* CAT	*F. tularensis*	*B. abortus*
MAMMALS: *Lepus americanus*	12	128	-	-	-
" "	14	-	-	40	-
Tamiasciurus hudsonicus	16	256	+	-	-
"	18	256	+	-	-
Microtus oeconomus	36	256	+	-	-
" "	75	-	-	40	-
" "	96	-	-	20	-
Microtus gregalis	154	-	-	40	-
" "	181	-	-	20	-
Clethrionomys rutilus	98	-	-	20	-
"	187	16	-	-	-
AVES: *Spizella arborea*	94	-	-	40	-
Lagopus lagopus	95	-	-	40	-

Table 43. Antibody titres from Alaskan animal tissues passed through second animals.

Species	Lab No.	*C. burnetii* CF	*C. burnetii* CAT	*F. tularensis*	*B. abortus*
MAMMALS: *Lepus americanus*	128	256	+	-	-
" "	14	-	-	40	-
Tamiasciurus hudsonicus	16	256	-	-	-
"	18	256	+	-	-
Microtus oeconomus	36	128	-	-	-
" "	211	512	+	-	-
" "	75	-	-	80	-
Microtus gregalis	154	-	-	40	-
" "	181	-	-	20	-
AVES: *Spizella arborea*	94	-	-	40	-
Lagopus lagopus	95	-	-	40	-

are not *C. burnetii*. We are not ready to begin the third animal passage of this material. No temperature curve suggestive of either organism has been observed in any of the experimental mammals.

All pools of ectoparasites (ticks and fleas) have proved negative thus far. We have passaged into animals twice and will begin third

passage in the near future.

As this report was in process of preparation, additional sera and tissues were received from Dr. Hufman and Mr. Molchan of Paxson and Eagle, respectively. I have just received word that Mr. Robert Rausch of the Alaska Department of Fish and Game has collected 200 tissues from carnivorous mammals, and anticipates 200 more by the end of the Lynx trapping season. A supplemental report will be submitted as soon as possible, as will the results pending for the third animal passage material now in progress.

As far as these data may be interpreted, it does not appear that any particular study site within the region is more favorable than the others. On the basis of habitat data from trap lines, we have no information to indicate that a particular habitat at a study site is a better source than another. However, I consider that these observations of the past summer constitute only a beginning.

Pruitt (in press) has noted: "One result of our study is to stress the importance of the cycle in arctic biology. This aspect can hardly be emphasized too much. We have seen how not only the numbers of individuals fluctuate markedly, but how the structure of the populations vary from species to species and within a single species. The shifts in food habits are undoubtedly accompanied by shifts in behavioral reactions. The changes in intensity of reproduction are manifestations of changes in physiological attributes.

It is safe to conclude, therefore, that any study of arctic biology (even such an esoteric aspect as physiological responses to environmental changes) must include the state of the cycle as a basic consideration." The state of the cycle is nowhere more important than in the study of disease incidence and degree of parasite infestation.

Consequently, we have given considerable emphasis to standardized population samples. Our collections, while not large, are therefore of especial value as base lines against which future incidence and infestation rates can be compared. We have mentioned earlier some of the frustrations that resulted from the remarkable low populations of small mammals over such a large part of Alaska. In some respects, however, 1964 was an ideal time to initiate such a study. We now have a base datum of incidence and infestation that corresponds to the "low" of the cycle. Future work should take advantage of this and follow the populations through their cyclic increase and decline. In the past, many medical-ecological investigations in Alaska have suffered because they did not take population states into consideration and were too limited in time.

We should also emphasize the importance of investigations throughout the cycle of the seasons. This is nowhere more important than in the taiga, where for over half the annual cycle the small mammals live under the snow cover.

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APPENDIX A: A LIST OF ALASKAN HAEMATOPHAGOUS INSECTS

This list has been compiled from various sources and from the personal collections of the writer. Other than for the Heleidae and Tabanidae, the list is reasonably complete. These two families of Diptera are not well-known and need further study. By the spring of 1965, a monograph af Alaskan Siphonaptera will be in press.

Those species preceeded by an asterisk (*) are now known to occur in the interior of Alaska (Tanana Valley). A question mark (?) indicates a probable record.

Ticks

Dermacentor andersoni Stiles

Dermacentor variabilis Say (possibly an erroneous record)

*Haemaphysalis leporis-palustris (Packard)

Ixodes angustus Neumann

Ixodes signatus Birula

Ixodes uriae White

*Rhipicephalus sanguineus (Latreille)

Parasitic Mites

*Dermanyssus gallinae (De Geer)

*Haemogamasus alaskensis Ewing

Haemogamasus ambulans (Thorell)

*Haemolaelaps glasgowi (Ewing)

*Hirstionyssus isabellinus (Oudemans)

*Laelaps alaskensis Grant

Laelaps kochi Oudemans

*Laelaps multispinosus Banks

*Trombicula alaskensis Brennan and Wharton

*Trombicula microti Ewing

Anoplura

Antarctophthirus callorhini (Osborn)

Antarctophthirus trichechi (Bohemann)

Echinophthirius horridus (von Olfers)

Enderleinellus nitzschi Fahrenholz

Enderleinellus suturalis (Osborn)

Hoplopleura acanthopus (Burmeister)

Hoplopleura sciuricola Ferris (on red squirrels)

Linognathus setosus (von Olfers)

Neohaematopinus laeviusculus (Grube)

**Pediculus humanus* Linnaeus

**Phthirus pubis* (Linnaeus)

**Polyplax alaskensis* Ewing

**Polyplax auricularis* Kellogg and Ferris

Proechinophthirius fluctus (Ferris)

Siphonaptera

Spilopsyllinae

**Hoplopsyllus glacialis lynx* (Baker)

Hystrichopsyllinae

Nearctopsylla brooksi (Rothschild)

Nearctopsylla hyrtaci (Rothschild)

**Rhadinopsylla* sp.

Ctenophthalminae

**Corrodopsylla c. curvata* (Rothschild)

Neopsyllinae

**Catallagia charlottensis* (Baker)

*Catallagia dacenkoi fulleri Holland

Delotelis hollandi Smit

Epitedia wenmanni (Rothschild)

Ischnopsyllidae

Myodopsylla gentilis Jordan and Rothschild

Leptopsyllinae

*Peromyscopsylla ostsibirica longiloba (Jordan)

Amphipsyllinae

*Amphipsylla marikovskii ewingi Fox

Amphipsylla sibirica pollionis (Rothschild)

?Ctenophyllus armatus terribilis (Rothschild)

Ceratophyllinae

?Amphalius runatus necopinus (Jordon)

*Ceratophyllus arcuegens Holland

Ceratophyllus balati Rosicky

*Ceratophyllus celsus celsus Jordan

*Ceratophyllus diffinis Jordan

*Ceratophyllus garei Rothschild

*Ceratophyllus gallinae (Shrank)

*Ceratophyllus idius Jordan and Rothschild

*Ceratophyllus lunatus tundrensis Holland

Ceratophyllus niger Fox

*Ceratophyllus riparius Jordan and Rothschild

*Ceratophyllus scopulorum Holland

*Ceratophyllus v. vagabundus (Bohemann)

Dasypsyllus gallinulae perpinnatus (Baker)

Dasypsyllus stejnegeri (Jordan)

*Malaraeus penicilliger dissimilis (Jordan)

Megabothris abantis (Rothschild)

*Megabothris calcarifer gregsoni Holland

*Megabothris groenlandicus (Wahlgren)

*Megabothris quirini (Rothschild)

Mioctenopsylla arctica hadweni (Ewing)

Mioctenopsylla traubi Holland and Jellison

Monopsyllus ciliatus protinus (Jordan)

Monopsyllus tolli (Wagner)

*Monopsyllus vison (Baker)

Nosopsyllus fasciatus (Bosc)

Opisodasys keeni (Baker)

*Opisodasys pseudarctomys (Baker)

Orchopeas caedens caedens (Jordan)

*Orchopeas caedens durus (Jordan)

*Oropsylla alaskensis (Baker)

*Oropsylla arctomys (Baker)

*Oropsylla idahoensis (Baker)

*Tarsopsylla octodecimdentata coloradensis (Baker)

Thrassis pristinus Stark

Vermipsyllidae

*Chaetopsylla floridensis Fox

*Chaetopsylla tuberculaticeps ursi (Rothschild)

Culicidae

It is convenient to list the mosquito species according to the Biotic Provinces as defined by Dice in 1943. The Hudsonian Biotic Provinces includes the Tanana Valley.

Eskimoan Biotic Province

Aedes communis (De Geer)

Aedes hexodontus Dyar

Aedes impiger (Walker)

Aedes nigripes (Zetterstedt)

Aedes punctor (Kirby)

Hudsonian Biotic Province

Aedes canadensis (Theobald)

Aedes cataphylla Dyar

Aedes cinereus Meigen

Aedes communis (De Geer)

Aedes decticus Howard, Dyar, and Knab

Aedes diantaeus Howard, Dyar, and Knab

Aedes excrucians (Walker)

Aedes fitchii (Felt and Young)

Aedes hexodontus Dyar

Aedes impiger (Walker)

Aedes implicatus Vockeroth

Aedes intrudens Dyar

Aedes nigripes (Zetterstedt)

Aedes pionips Dyar

Aedes pullatus (Coquillett)

Aedes punctor (Kirby)

Aedes riparius Dyar and Knab

Aedes stimulans (Walker)

Anopheles earlei Vargas

Culex territans Walker

Culiseta alaskaensis (Ludlow)

Culiseta impatiens (Walker)

Culiseta morsitans (Theobald)

Sitkin Biotic Province

Aedes aboriginis Dyar

Aedes cinereus Meigen

Aedes communis (De Geer)

Aedes excrucians (Walker)

Aedes pionips Dyar

Aedes pullatus (Coquillett)

Aedes punctor (Kirby)

Culiseta alaskaensis (Ludlow)

Culiseta impatiens (Walker)

Culiseta incidens (Thomson)

Culiseta morsitans (Theobald)

Culiseta particeps (Adams)

Heleidae

Culicoides alaskensis Wirth

Culicoides cockerellii (Coquillett)

Culicoides obsoletus (Meigen)

Culicoides tristriatulus Hoffman

Culicoides unicolor (Coquillett)

Culicoides yukonensis Hoffman (very abundant in the interior, probably a complex of species)

Simuliidae

Cnephia emergens Stone

Cnephia eremites Shewell

Cnephia minus (Dyar and Shannon)

Cnephia mutata (Malloch)

*Cnephia saileri Stone

Cnephia sommermanae Stone

Gymnopais holopticus Stone

*Prosimulium alpestre Dorogostajskij, Rubzov, and Vlasenko

Prosimulium borealis Malloch

Prosimulium decemarticulatum (Twinn)

Prosimulium dicum Dyar and Shannon

Prosimulium fulvum (Coquillett)

*Prosimulium hirtipes (Fries)

Prosimulium onychodactylum Dyar and Shannon

Prosimulium pleurale Maloch

*Prosimulium travisi Stone

Prosimulium ursinum (Edwards)

Simulium sureum Fries

Simulium baffinense Twinn

Simulium bicornis Dorogostajskij, Rubzov, Vlasenko

Simulium furculatum Shewell

*Simulium gouldingi Stone

Simulium latipes (Meigen)

Simulium pugetense (Dyar and Shannon)

Simulium arcticum Malloch

Simulium corbis Twinn

**Simulium decorum* Walker

Simulium hunteri Malloch

Simulium malyschevi Dorogostajskij, Rubzov and Vlasenko

Simulium meridionale Riley

Simulium nigricoxum Stone

Simulium rubtzovi Smart

Simulium rugglesi Nicholson and Mickel

Simulium tuberosum (Lundstroem)

**Simulium venustum* Say

**Simulium vittatum* Zetterstedt

Tabanidae (definitely incomplete)

Atylotus insuetus (Osten Sacken)

**Chrysops carbonaria* Walker

**Chrysops furcata* Walker

**Chrysops nigripes* Zetterstedt

Chrysonzona americana (Osten Sacken)

**Tabanus affinis* (Kirby)

Tabanus astuta (Osten Sacken)

Tabanus boreus (Stone)

**Tabanus epistates* (Osten Sacken)

**Tabanus frontalis* (Walker)

Tabanus illota (Osten Sacken)

Tabanus septentrionalis (Loew)

**Tabanus sexfasciata* (Hine)

**Tabanus sonomensis* (Osten Sacken)

Rhagionidae

**Symphoromyia atripes* Bigot

APPENDIX B: CHECKLIST OF THE MAMMALS OF THE TANANA VALLEY (Within 100 miles of Fairbanks)

Order Insectivora

Sorex arcticus

Sorex cinereus

Sorex obscurus

Microsorex hoyi

Order Chiroptera

Myotis lucifugus

Eptesicus fuscus

Order Carnivora

Ursus americanus

Ursus horribilis

Martes americana

Mustela rixosa

Mustela erminea

Mustela vison

Gulo luscus

Lutra canadensis

Vulpes fulva

Canis latrans

Canis lupus

Lynx canadensis

Order Rodentia

Marmota caligata

Citellus parryi (=_Spermophilus undulatus_ auct.)

Tamiasciurus hudsonicus

Glaucomys sabrinus

?_Peromyscus maniculatus_

Castor canadensis

?_Synaptomys borealis_

Lemmus trimucronatus

Clethrionomys rutilus

Microtus pennsylvanicus

Microtus oeconomus

Microtus gregalis (=_M. miurus_ auct.)

Microtus longicaudus

Microtus xanthognathus

Ondatra zibethicus

Rattus norvegicus

Mus musculus

Zapus hudsonius

Erethizon dorsatum

Order Lagomorpha

Ochotona collaris

Lepus americanus

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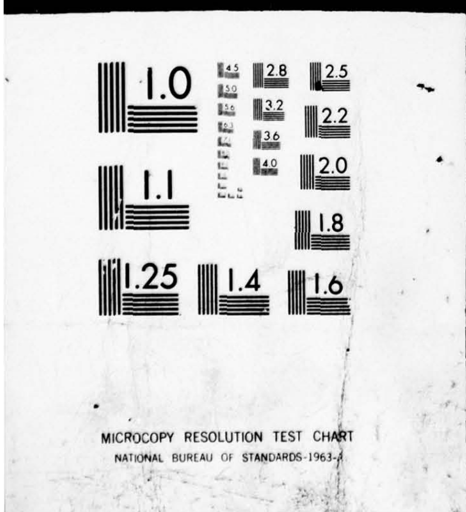

Order A

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Order Artiodactyla

Bison bison

Alces alces

Rangifer tarandus

Ovis dalli